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15. Investigation of the surface water quality parameters in the predeltaic area of the Danube Delta in 2017. Study case: Somova - Parcheș aquatic complex lakes

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Abstract: A research study was conducted to characterize the status of the surface water quality of the Parcheș, Babele, Petica and Somova lakes, situated in the Somova - Parches aquatic complex, located West of Tulcea (Romania), nearby of the industrial area. Water samples were gathered from several sampling points of each lake and investigated for various physico-chemical parameters including water depth (m), temperature (^oC), pH (units), DO (mg/l), $N\text{-}NO_2^-$ (mg/l), $N\text{-}NO_3^-$ (mg/l), $P\text{-}PO_4^{3-}$(mg/l), EC (µS/cm), TDS (mg/l), SO_4^{2-}(mg/l), turbidity (NTU), TSS (mg/l), transparency (m), chlorophyll "a" (µg/l), SiO_2 (mg/l), H_2S (mg/l), S^{2-} (mg/l) etc., during the period of October 2017. Different tested environmental indicators showed a considerable range of values in all investigated lakes. In addition, disparate punctual sampling points were chosen from every lake to assess the levels of selected heavy metals of interest in surface water. Generally, no significant exceedances of the investigated heavy metals were recorded excepting elements as Ba, Mn, Ni and Se which showed slight variations for each parameter associated with the Class I, and, respectively, Class II category, in comparison to the maximum allowable limits established by the water quality standards. The results from this study indicated that the physico-chemical characteristics and surface water quality from the Somova - Parcheș aquatic complex may be different due to the natural context (*e.g.,* regional differences in land use, hydrology, underlying geology, climate, flowing regime etc.) and anthropogenic effects of industrial activities that take place in the Tulcea town area.
Keywords: assessment, environmental indicators, predeltaic area, surface water, water quality

INTRODUCTION

Somova - Parcheș lacustrine complex is situated in the predeltaic area of the Danube Delta Biosphere Reserve (DDBR), near the border between Romania and Ukraine. Somova - Parcheș aquatic complex is located upstream of the entrance of the Danube Delta, one of the Europe's inestimable value habitats and ecosystems in terms of specific delta wildlife and biodiversity. Acknowledged as a UNESCO Biosphere Reserve, a World Cultural and Natural Heritage site, as well as a Ramsar Wetland (*****, 1987), it is continent's second largest delta (after the Volga Delta), and the best preserved of Europe river deltas.

The Somova - Parcheş hydrographic unit is located in the upstream area of the Danube Delta (upstream of the Tulcea county) and is under the direct influence of the Danube River. The Danube River is the major regular and a voluminous supply of water in Romania, including important water-related protected areas for species and habitat protection. Somova - Parcheș aquatic complex receives, a significant volume of freshwater inflow from the Danube River, particularly during spring season. The human-related activities in an upstream catchment of the Danube River, as well as local pressures, can be the main sources of water contaminants in the river. In addition, human interventions in the floodplains of the Danube River and its major tributaries have repercussions in downstream areas of the Danube River (Gâștescu and Tuchiu, 2012).

In the vast aquatic deltaic-lagoon ecosystem assemblage (i.e., DDBR), every hydrographic entity demands a special attention due to their importance, as being a suitable habitat environments for

several aquatic species of interest (e.g., rare species of plants and animals), (Gâştescu and Ştiucă, 2008), as well as their natural vulnerability to environmental imbalance (Bucx *et al.,* 2010).
In this context, characterizing and assessing the potential anthropogenic and natural pressures on lake ecosystems belonging to this predeltaic area became important, due to their direct consequences for a wide spectrum of ecosystem components of the downstream Danube Deltas areas.

Several recent previous research studies have focused on the Somova - Parcheș area, taking into consideration investigations on aquatic communities (*e.g.,* fishes) with due to regarding for the promoting species coexistence in the studied aquatic complex, as well as for the development of sustainable management within the DDBR (Năstase and Oțel, 2011). Other studies have focused on the heavy metal accumulation, temporal trends and their evolution in this predeltaic area (Burada *et al.,* 2015; Tudor *et al.,* 2016) aiming to assess the environmental impact of pollutants in aquatic systems. As well, (Seceleanu-Odor *et al.,* 2016) has been focused on the study of inorganic nutrient dynamics in surface water, in order to evaluate the physico-chemical characteristics and surface water quality of the Somova - Parcheș area.

The aim of the present study was to assess the physico-chemical characteristics of surface water from Somova - Parcheș lacustrine complex lakes in order to estimate the water quality status and trends at a number of sampling stations.
Typically, changes in water quality of this area may occur under several aspects, as a result of natural factors or significant anthropogenic pressures as touristic activities, a variety of naval-related activities and several industrial centers that lie in close proximity of the evaluated predeltaic area of the Danube Delta.

MATERIALS AND METHODS

Study area

The DDBR (5800 km^2) is composed of the Danube alluvial plain (Isaccea-Tulcea sector, 102 km^2), also known as the Somova - Parcheș lacustrine complex, the Danube Delta itself (3510 km^2), the Razim-Sinoie Lagoon Complex (1145 km^2), the marine coastal waters (20 izobath, 1030 km^2) and the Danube River between Cotul Pisicii and Isaccea (13 km^2), (Gâştescu, 2009). Each sector has specific characteristics that may be unique to a particular area, as hydrology, geomorphology, distinct species and communities of plants and animals, etc.
This research was performed to assess the physical and chemical parameters of surface water from Somova - Parcheș lacustrine complex (**Fig. 1**).

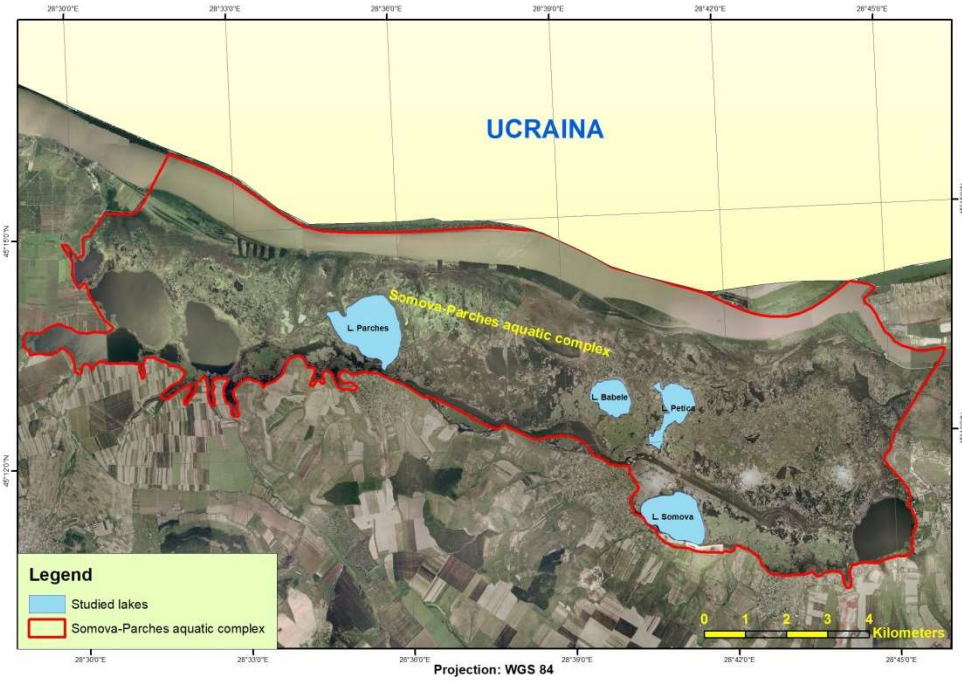

Figure 1. Map showing the study area

The sampled lakes were chosen without regard their „anticipated" water chemistry. An important selection consideration was based on the accessibility of lakes during the period when the water levels of canal waterways between lakes were lowered.
The water samples were gathered from forty-two water stations in the Somova - Parcheș lacustrine complex in October 2017. The sampling sites were uniformly distributed on a grid established by a randomly selected starting point (Fig.2).
In this study, the classical analytical methods for determining the in-situ and ex-situ water quality indicators were performed, using regular chemical reagents and water quality testing equipment.

Figure 2. The locations of the sampling points within the Somova - Parcheș aquatic complex in October 2017

In-situ parameters were measured immediately at the sampling locations aboard the fluvial research boat belonging to the GeoEcoMar Institute, and ex-situ parameters were analyzed in other external laboratories in conformity to the environmental standard methods.
Water quality testing equipment was used for measuring the water physical-chemical parameters, as WTW Multiline P4 Multiparameter (dissolved oxygen, temperature, electrical conductivity, total dissolved salts, pH), HACH 2100Q (turbidity), HACH 5000 - UV-Vis – Spectrophotometer (nitrates, nitrites, phosphates, sulfates).
Determination of the distribution of the heavy metal concentrations in water was performed within the Water Pollution Control Laboratory belonging to INCD ECOIND Bucharest. The treatment of the water samples for analyzes was carried out according to the standard SR EN ISO11885:2009.

RESULTS AND DISCUSSIONS

As a valuable natural resource, water is an important element for the proper functioning conditions of the environment. Water quality maintains the ecological processes that favor the development of populations of animal and plant species and their interactions with the ecosystems to which they belong (water, water-temperature, plants, animals, sunlight, water-sediment interface, etc.). In this context, the assessment of the ecological status of lakes is a basic issue for the monitoring activities in order to rally to the principles of sustainable water management set out by the EU - WFD (*****,2000/60/EC).
The surface water quality assessment was mainly performed according to the provisions of the water quality guidelines in Romania - Order of the Ministry of Environmental and Water No. 161/2006 (for the Approval of the Norm Concerning the Reference Objectives for the Surface Water Quality Classification, Official Journal of Romania, Part 1, No 511 bis). Subsequently, several environmental standards were taken into consideration to assess the environmental indicators as TDS (total dissolved solids content), (DeZuane, 1997), turbidity (STAS 6323 – 88), TSS (total suspended solids), (*****, ANZECC 2000 Guidelines) and silica (http://www.freedrinkingwater.com/water_quality/quality2/j-24-typical-concentrations-for-silicates-ground-n-surface-waters.htm).
The resulting water quality outcomes expressed as the minimal, maximal and average value of each parameter per investigated lakes is shown in Table 1. Overall, the results indicated that physico-

chemical parameters of the surface water were within the permissible limits. In general, the measured physico-chemical parameters showed comparable average values without significant exceedances, excepting some punctual situations which are presented further on.

Table 1. Synthesis of the water physico-chemical parameters

PARCHEŞ (n = 15)	Value	**Ad (m)**	**T (°C)**	**pH (units)**	**O_2 (mg/l)**	**O_2 (%)**	**N-NO_2^- (mg/l)**	**N-NO_3^- (mg/l)**	**P-PO_4^{3-} (mg/l)**	**Chla (µg/l)**
	min	0.80	14.80	8.24	12.76	125.40	0.01	0.01	0.03	6.70
	max	2.2	16.7	9.1	16.66	166.6	0.021	0.04	0.116	15.18
	mean	1.08	15.54	8.59	14.69	145.65	0.01	0.02	0.06	10.54
	Value	**EC (µS/cm)**	**TDS (mg/l)**	**SO_4^{2-} (mg/l)**	**Turb (NTU)**	**TSS (mg/l)**	**VDS (m)**	**SiO_2 (mg/l)**	**H_2S (mg/l)**	**S^2 (mg/l)**
	min	348.00	174.00	20.00	10.70	18.00	0.20	4.80	0.0010625	0.0010
	max	380	190	30	61.8	61	0.5	8.3625	0.01328125	0.0125
	mean	360.2	180.1	26.89	47.51	46.53	0.31	6.16	0.0053125	0.0050
BABELE (n = 9)	Value	**Ad (m)**	**T (°C)**	**pH (units)**	**O_2 (mg/l)**	**O_2 (%)**	**N-NO_2^- (mg/l)**	**N-NO_3^- (mg/l)**	**P-PO_4^{3-} (mg/l)**	**Chla (µg/l)**
	min	0.8	14.4	7.7	6.15	58.7	0.006	0.01	0.033	7.43
	max	1.4	14.7	8.14	8.46	82.2	0.008	0.02	0.043	11.76
	mean	0.955	14.6	7.90	7.4055	71.933	0.007	0.01	0.037	9.85
	Value	**EC (µS/cm)**	**TDS (mg/l)**	**SO_4^{2-} (mg/l)**	**Turb (NTU)**	**TSS (mg/l)**	**VDS (m)**	**SiO_2 (mg/l)**	**H_2S (mg/l)**	**S^2 (mg/l)**
	min	390	195	6	3.54	10	0.5	7.6625	0.0010625	0.001
	max	418	209	9	10.8	18	0.8	8.8325	0.0031875	0.003
	mean	396.56	198.28	8.00	6.96	14.11	0.7	8.25	0.0021250	0.002
PETICA (n = 6)	Value	**Ad (m)**	**T (°C)**	**pH (units)**	**O_2 (mg/l)**	**O_2 (%)**	**N-NO_2^- (mg/l)**	**N-NO_3^- (mg/l)**	**P-PO_4^{3-} (mg/l)**	**Chla (µg/l)**
	min	0.4	15.3	7.92	9.1	90.6	0.006	0.01	0.016	2.32
	max	0.8	15.8	8.23	11.24	111	0.015	0.02	0.02	7.48
	mean	0.65	15.55	8.121	10.21	101.4	0.0103	0.017	0.0173	4.30
	Value	**EC (µS/cm)**	**TDS (mg/l)**	**SO_4^{2-} (mg/l)**	**Turb (NTU)**	**TSS (mg/l)**	**VDS (m)**	**SiO_2 (mg/l)**	**H_2S (mg/l)**	**S^2 (mg/l)**
	min	376	188	1	1.43	2	0.25	0.7125	0.002125	0.002
	max	434	217	8	15.3	18	0.8	2.2225	0.0032	0.003
	mean	393.33	196.67	3.333	5.515	7.167	0.575	1.35667	0.0027	0.0025
SOMOVA (n = 12)	Value	**Ad (m)**	**T (°C)**	**pH (units)**	**O_2 (mg/l)**	**O_2 (%)**	**N-NO_2^- (mg/l)**	**N-NO_3^- (mg/l)**	**P-PO_4^{3-} (mg/l)**	**Chla (µg/l)**
	min	1	15.2	8.11	8.81	86.7	0.006	0.01	0.016	7.01
	max	1.4	16.1	8.41	10.57	105.3	0.015	0.02	0.036	9.22
	mean	1.27	15.55	8.22	9.98	98.85	0.011	0.0166	0.026	7.82
	Value	**EC (µS/cm)**	**TDS (mg/l)**	**SO_4^{2-} (mg/l)**	**Turb (NTU)**	**TSS (mg/l)**	**VDS (m)**	**SiO_2 (mg/l)**	**H_2S (mg/l)**	**S^2 (mg/l)**
	min	402	201	23	10.3	16	0.4	8.075	0.0010625	0.001
	max	410	205	28	18.5	22	0.7	9.565	0.00425	0.004
	mean	404.5	202.25	26	14.74	18.25	0.53	8.8575	0.002125	0.002

The average water temperature distribution was consistent with the expected seasonal variations for the period of autumn. The values of the surface water temperature varied in a relatively narrow range, as follows: Parcheş L. (14.8 - 16.7 °C; mean = 15.54 °C), Babele L. (14.4 – 14.7 °C; mean = 14.6 °C), Petica L. (15.3 - 15.8 °C; mean = 15.55 °C) and Somova L. (15.2 - 16.1 °C; mean = 15.55 °C).

The pH value of the lakes varied slightly in the four lacustrine perimeters. Regarding the pH measured in the tested water samples it was observed that the obtained values are included in the pH range of the neutral values which sometimes go up to a slightly alkaline pH, as follows: Parcheş L. (8.24 - 9.1 pH units; mean = 8.59 pH units), Babele L. (7.7 - 8.14 pH units; mean = 7.90 pH units), Petica L. (7.92 - 8.23 pH units; mean = 8.12 pH units) and Somova L. (8.11 - 8.41 pH units; mean = 8.22 pH units).

All the lakes were generally well-aerated with a high amount of oxygen dissolved in water. The distribution of dissolved oxygen investigated in the lakes' waters had a relatively wide range of variations: Parcheş L. (12.76 - 16.66 mg/l; mean = 14.69 mg/l), Babele L. (6.15 - 8.46 mg/l; mean = 7.41 mg/l), Petica L. (9.1 - 11.24 mg/l; mean = 10.21 mg/l) and Somova L. (8.81 - 10.57 mg/l; mean = 9.98 mg/l).

The nutrient dynamics displayed relatively narrower fluctuations in the framework of the investigated lacustrine areas. Regarding the nitrate nitrogen (N-NO_2^-) concentration, it was observed that the limit of the maximum allowable quantity corresponding to the permissible values for the first class of water

quality (very good ecological status) has been exceeded in some samples taken from the Parcheş, Petica and Somova lakes. The recorded values varied as follows: Parcheş L. (0.01 - 0.021 mg/l; mean = 0.01 mg/l), Babele L. (0.01 - 0.02 mg/l; mean = 0.01 mg/l), Petica L. (0.006-0.015 mg/l; mean = 0.0103 mg/l), and Somova L. (0.006-0.015 mg/l; mean = 0.011 mg/l). Nitrate nitrogen ($N\text{-}NO_3^-$) concentrations tested in the collected water samples showed very low values below the permissible values for the first class of water quality (very good ecological status).

The values of the concentrations of orthophosphates ($P\text{-}PO_4^{3-}$) obtained in the tested water samples were fluctuating, as follows: Parcheş L. (0.03 – 0.116 mg/l; mean = 0.6 mg/l), Babele L. (0.033-0.043 mg/l; mean = 0.037 mg/l), Petica L. (0.016-0.02 mg/l; mean = 0.0173 mg/l), and Somova L. (0.016-0.036 mg/l; mean = 0.026 mg/l); it was noted that they exceed the limits of the permissible values for the first class of water quality (very good ecological status), in some samples of water taken from Parcheş L.

The concentration of chlorophyll "a" (Chla) measured in some water samples from the investigated lakes ranged as follows: Parcheş L. (6.70 - 15.18 µg/l; mean = 10.54 µg/l), Babele L., (43 - 11,76 µg/l; mean = 9.85 µg/l), Petica L. (2.32 – 7.48 µg/l ; mean = 4.30 µg/l) and Somova L. (7.01 - 9.22 µg/l; mean = 7.82 µg/l). It was observed that the tested samples did not show values exceeding the permissible values for the first class of water quality (very good ecological status).

The electrical conductivity (EC) tested on the samples of the water samples had a relatively narrow variation, as follows: Parcheş L. (348-380 µS/cm; mean = 360.2 µS/cm), Babele L. (390-418 µS/cm; mean = 396.56 µS/cm), Petica L. (376 - 434 µS/cm; mean = 393.33 µS/cm) and Somova L. (402-410 µS/cm; mean = 404.5 µS/cm). The values obtained do not exceed the limit imposed by the current legislation, corresponding to the permissible values for the first class of water quality (very good ecological status).

The content of TDS (total dissolved organic and inorganic substances) analyzed in water samples had values as follows: Parcheş L. (174 - 190 mg/l; mean =180.1 mg/l), Babele L. (195-209 mg/l; mean =198.28 mg/l), Petica L. (188-217 mg/l; mean = 196.67 mg/l) and Somova L. (201 - 205 mg/l; mean = 202.25 mg/l).

The concentration of sulphates (SO_4^{2-}) fluctuates, and had the following values: Parcheş L. (20-30 mg/l; mean = 26.89 mg/l), Babele L. (6-9 mg/l; mean = 8 mg/l), Petica L. (1 - 8 mg/l ; mean = 3.33 mg/l) and Somova L. (23-28 mg/l ; mean = 26 mg/l); no exceedances of the permissible values for the first class of water quality (very good ecological status) were recorded in the tested samples.

The turbidity values measured in the water samples taken from all the lakes varied in a relatively wide range, with high values, as follows: Parcheş L. (10.70 - 61.8 NTU; mean = 47.51 NTU), Babele L. (3.54 - 10.8 NTU; mean = 6.96 NTU), Petica L. (1.43 - 15.3 NTU; mean = 5.51 NTU) and Somova L. (10.3-18.5 NTU; mean = 14.74 NTU). Most of the tested samples had higher turbidity values.

The distribution of the TSS concentration (total suspended solids) in the investigated water samples had the following values: Parcheş L. (18 - 61 mg/l; mean =46.53 mg/l), Babele L. (10-18 mg/l; mean = 14.11 mg/l), Petica L. (2-18 mg/l; mean = 7.16 mg/l and Somova L. (16-22 mg/l; mean = 18.25 mg/l). Significantly increased TSS (total suspended solids) contents were noticed in most of the tested water samples gathered from Parcheș L. The water transparency fluctuated as follows: Parcheş L. (0.2 – 0.5 m; mean =0.31 m), Babele L. (0.5 – 0.8 m; mean = 0.7 m), Petica L. (0.25 – 0.8 m; mean = 0.57 m) and Somova L. (0.4 – 0.7 m; mean = 0.53 m).

Silica is an essential nutrient for aquatic organisms (e.g., diatoms), (http://www.freedrinkingwater.com/water_quality/quality2/j-24-typical-concentrations-for-silicates-ground-n-surface-waters.htm).The values determined for the SiO_2 content varied as follows: Parcheş L. (4.80 - 8.32 mg/l; mean = 6.16 mg/l), Babele L. (7.66 - 8.83 mg/l; mean = 8.25 mg/l), Petica L. (0.71 - 2.22 mg/l; mean = 1.35 mg/l) and Somova L. (8.07 - 9.56 mg/l; mean = 8.85 mg/l).

In order to identify the heavy metal concentrations in surface water samples, disparate punctual sampling points were selected as follows: Parcheş L. (4 stations), Danube C. (1 station), Babele L. (1 station), Petica L. (1 station) and Somova L. (3 stations). The results of the heavy metal concentrations are shown in Table 2. In general, no significant exceedances of the investigated elements were recorded. An exception was represented by Ba that presented values that exceeded the permissible values for the first and second class of water quality (very good ecological status, respectively good ecological status) (Babele and Somova L.), Mn that showed values that exceeded the permissible values for the first class of water quality (very good ecological status) (Parcheş and Somova L.), Ni that exceeded the permissible values for the first class of water quality (very good ecological status) (Danube C.) and Se that presented values that exceeded the permissible values for the first class of water quality (very good ecological status) (Parcheş and Somova L).

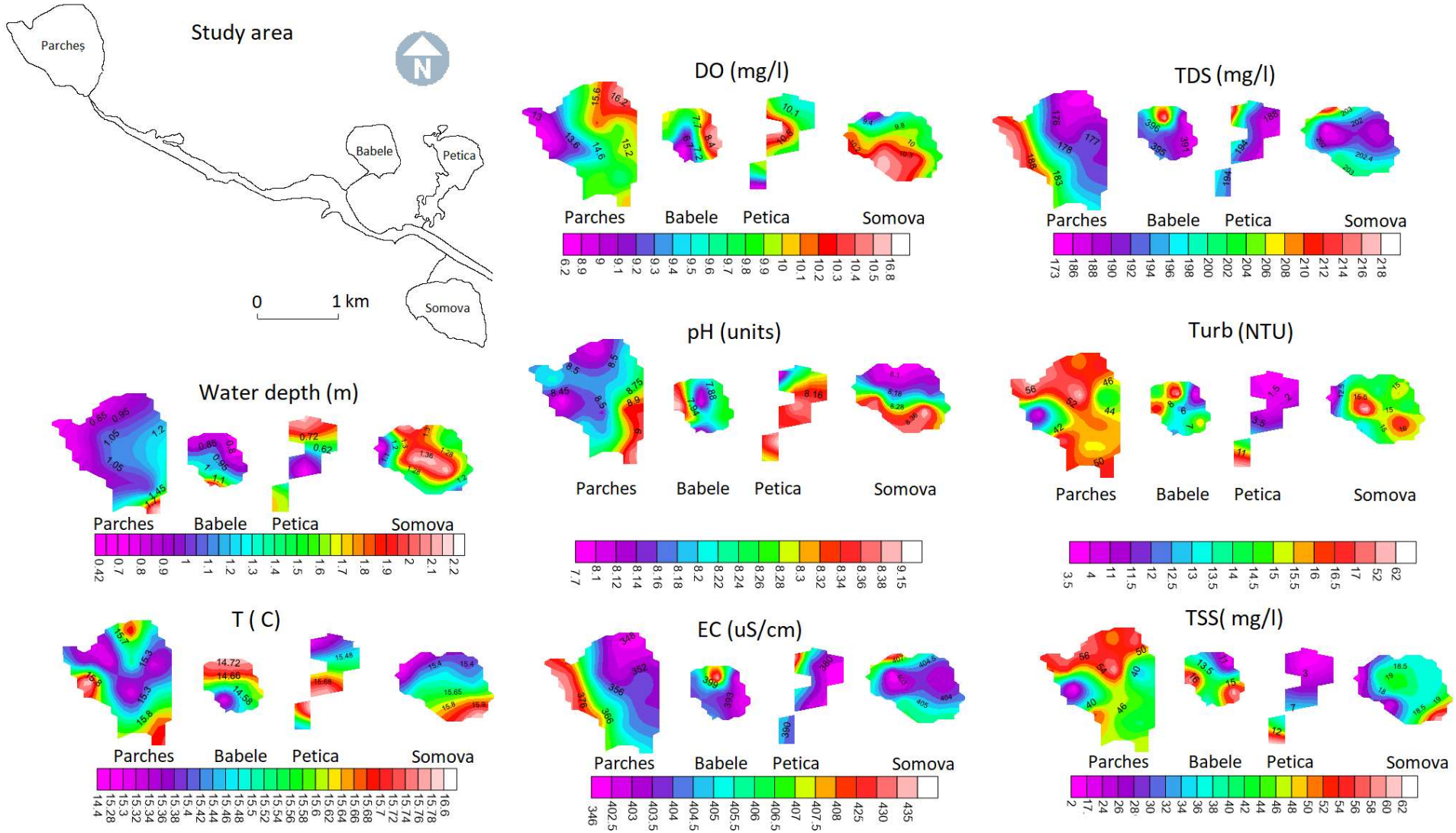

Fig 3. Spatial variation of selected physico-chemical parameters of surface water

Table 2. The distribution of the heavy metal concentrations in the investigated water samples

Sampling sites	Sample	As µg/l	Ba mg/l	Cd µg/l	Cr µg/l	Co µg/l	Cu µg/l	Fe mg/l	Mn mg/l	Ni µg/l	Pb µg/l	Se µg/l	Zn µg/l
Parcheș	**DD17-185**	2.1	0.0333	<0.4	<1.3	<0.75	1.7	0.0629	0.0373	<1.2	0.6	<0.34	5.4
Parcheș	**DD17-189**	2	0.0314	<0.4	<1.3	<0.75	1.6	0.0873	0.0519	3.5	0.9	1.2	4.3
Parcheș	**DD17-190**	2.5	0.0336	<0.4	<1.3	<0.75	1.6	0.0959	0.0474	<1.2	0.4	<0.34	4.4
Ivanova	**DD17-201**	1.6	0.0456	<0.4	4.4	<0.75	1.7	0.0459	0.0212	18.4	0.2	<0.34	10.9
Babele	**DD17-206**	2.9	0.198	<0.4	<1.3	<0.75	1.5	0.0305	0.0368	<1.2	0.8	<0.34	4.9
Petica	**DD16-215**	3.5	0.0432	<0.4	<1.3	<0.75	1.3	0.004	0.0157	<1.2	<0.15	<0.34	4.7
Somova	**DD17-219**	2.1	0.0337	<0.4	3.5	<0.75	1.1	0.002	0.0072	<1.2	<0.15	<0.34	3.9
Somova	**DD17-221**	3	0.252	<0.4	<1.3	<0.75	1.8	0.0666	0.0687	<1.2	3.8	1.1	4.3
Somova	**DD17-225**	2.2	0.259	<0.4	<1.3	<0.75	2	0.0532	0.0595	<1.2	2.6	<0.34	5.7
Somova	**DD17-230**	3.8	0.25	<0.4	<1.3	<0.75	2	0.0596	0.0495	<1.2	3.6	1.2	4.4

The results obtained from the data analysis allowed the development of spatial mapping of the specific indicators in the surface waters of the investigated lakes (Fig.3).

CONCLUSIONS

In a relatively small area, the Somova - Parcheș lacustrine complex, compress several types of unique geomorphological landscapes, as a series of lakes chained together by many canals and backwaters, hills, wine-growing areas and mountains (*e.g.,* Măcin mountains) in the distance.

The lake sites hosts' marsh plants (emergent aquatic macrophytes), floating vegetation reeds, reeds along the lake margins, and diverse native flora and fauna, making this complex significant for geo-ecological dynamics, as well as for scientific reasons. Due to its freshwater ecosystem biodiversity, the Somova - Parcheș lacustrine complex ranks, particularly high in terms of numerous bird colonies (pelicans and cormorants, coots, wild ducks, and hawks), cyprinid fish species (*e.g.,* Rotundu Lake), etc.

In spite of its biodiversity significance of the area, very little information is available and has been disseminated too, in relation to physico-chemical characteristics of water and sediments in the Somova - Parcheș lacustrine complex, even though the area owes its individualities to geomorphological environments (*e.g.,* flooded area with large amplitudes of the flood wave).

In this circumstance, this study attempts to contribute to a knowledge gap by presenting the physico-chemical characteristics of surface water and assessing the data in the context of the water-rich environments of the area.

The water quality of the investigated lakes depends on individual and local circumstances as the Danube River water level, flood regime, meteorological conditions, diurnal and seasonal variations, etc. as well as human related-activities that occur in close proximity of the evaluated predeltaic area of the Danube Delta.
Overall, the results showed that the investigated physico-chemical parameters met the criteria for the first and second class, accordingly, very good and good ecological status.

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