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BASIC DATA CONCERNING THE WATER QUALITY AND RECENT SEDIMENTATION IN ABANDONED CHANNELS LOCATED WITHIN THE DANUBE DELTA – SF. GHEORGHE ARM

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ABSTRACT

The oxbow lakes are a unique type of lakes settled in the floodplains of large rivers, in an abandoned meander curvature of a river channel. In this study, we assess the environmental quality status (water and sediment) in three different oxbow lakes formed from the Sf. Gheorghe distributary, the oldest branch of the Danube River. The research was focused on specific field work, subsequent laboratory analysis, data processing and interpretation. In this sense, 30 water and 30 surficial sediment samples, as well as 2 short cores have been gathered during the October 2015 sampling campaign, to estimate the water physico-chemical properties and the lithological character of the recent sediments. The investigated lakes are Gorgostel, Erenciuc and Belciug, disposed from upstream to downstream, namely from west to east in the deltaic areal. The Gorgostel Lake is located in the upper fluvial delta plain and the others as Erenciuc and respectively Belciug are situated in the lower marine delta plain. These lakes are not completely isolated, being further supplied by waterway of different streams or canals. The analytical data show that, Secchi transparency (m), temperature (°C), dissolved oxygen (mg/l), conductivity (μS/cm), total dissolved solids (mg/l), pH (units), redox potential (mV), turbidity (NTU), suspended solids (mg/l), nitrates (mg/l), nitrites(mg/l), orthophosphates (mg/l) and sulphates (mg/l) are found to be generally, in accordance with environmental regulations. The results expressed as an average value of the water quality parameters varied conforming to the local conditions, sampling stations, seasonal changes in the water budget through lakes etc. The percentage distribution results of the physical sediment parameters as moisture and dry content, as well as total organic matter, total carbonates and siliciclastic fraction, also fluctuates in function of the specific local conditions of the studied areas. The main findings did not notify major differences between the investigated areas. Overall, the obtained results were mainly argued by the sampling locations and seasonal change issues. In conclusion, this study report that the water quality investigated in these particular lakes is in a sustainable condition. The particular environmental conditions of lakes speed up the accumulation of the total organic matter that is assured by autochthonous sources. The acquired results could be base for future studies concerning the oxbow lakes evolution.

Keywords: shallow oxbow lakes, freshwater, physico-chemical, sediments, parameters, organic matter.

1 INTRODUCTION

The Danube River (the longest river in the European Union - and the second longest on the continent) springs in the Black Forest of Germany and flows in a southeast direction through central and eastern Europe, passing through many countries before draining into the Black Sea through the medium of the Danube Delta, in Romania and Ukraine. The river generates a wide branching delta into the Black Sea, a much elaborated complex of ecosystems whose hydrological network extended between the three arms: Chilia, Sulina and Sf. Gheorghe. The Danube Delta is located in the northwestern part of the Black Sea, between 44°25' and 45°37' N latitude and between 28°45' and 29°46' E longitude, bounded by the Bugeac Plateau to the North and by the Dobrogea Unit to the South (Panin 1996). In the past decades, there have been intensive anthropogenic pressures on the Danube River and the Danube Delta. The most important modifications are represented by the hydro technical works carried out in the Romanian sector of the Danube River (e.g., Iron Gates I and II dams) as well as, other works needed to improve and regulate navigation of the Danube River distributaries (e.g., Sulina and Sf. Gheorghe). Danube Delta as an environmental system is one of the main integral part of the Danube River - Danube Delta - Black Sea geoecosystem (Gâştescu and Ştiucă 2008). As Europe's biggest subsisting natural wetland and representing a worldwide valuable region, the Danube Delta is one of the continent's most inestimable environments for plant and animal biodiversity. But in the same time, the Danube Delta's environmental condition is disturbing and complex and its ecosystems are influenced particularly by anthropogenic processes originated from human activities (industry, agriculture, transport, tourism, regulation operations on the distributaries and realization of a network of canals into inner delta, unreasonable exploitation of the Danube Delta natural resources etc.). As a result of hydro technical improvements, the irrational exploitation of the natural resources, and other upstream influences, it was produced a general disagreement in the hydrological regime of the Danube Delta, mainly manifested by disturbances of flow and water circulation, alluviums, salts and biomasses, on principal distributaries and in the inner delta, as well as by perturbation of internal and outlying morphological processes of the delta (Bondar 1993). The present paper is focused on the quality assessment of surface water and sediment investigated in three different oxbow lakes formed from the Sf. Gheorghe distributary, the oldest branch of the Danube River. This paper presents in a synthetic way the results acquired during October 2015.

2 MATERIALS AND METHODS
2.1 Study area and the environmental setting

The Danube Delta has a very specific hydrological regime and its labyrinthine hydrographic network is a very complex system of river channels, streams, artificial canals, shallow bays, ponds and numerous lakes, intermixed with swamps, reed-beds, isles and floodplains that creates the unique natural ecosystems of the delta region. Sf. Gheorghe distributary, the oldest branch of the Danube River belongs to the hydrological system of the Danube Delta. The intense hydro technical development works (occurred between 1983 and 1989) aiming to improve the navigation on the river branches could be considered as an intrusive anthropogenic factor that has led to modifications over time in the Danube Delta area. The Danube Delta is composed of two main units - the fluvial delta plain (an upper unit situated in the west) and the fluvio-marine delta plain (a lower unit located in the east, up to the Black Sea) being subdivided by the initial littoral ridge: Jibrieni-Letea-Răducu-Ceamurlia-Caraorman-Sărăturile-Perișor-Lupilor (Panin 1996).

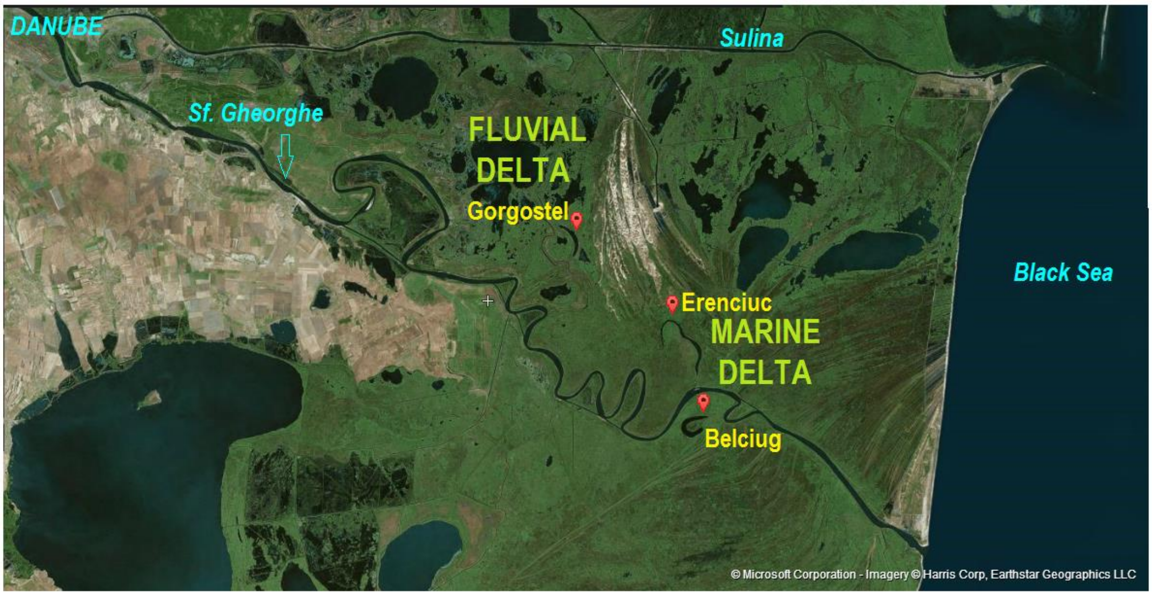

Figure 1. Location of the investigated lakes within Danube Delta area

The investigated lakes are Gorgostel, Erenciuc and Belciug, disposed from upstream to downstream, namely from west to east in the deltaic areal. These lakes are not completely abandoned, being further supplied by waterway of different streams or canals. The Gorgostel Lake (Fig. 1) is located in the upper fluvial delta plain and is a reminiscence of a Sf. Gheorghe branch of the Danube (Basarab et al. 1998), which was subsequently silted up. This lake is linked by the Perivolovca stream. Erenciuc is an isolated lake (Fig. 1) situated in the lower marine delta plain. The lake's length is only 308 m, being oriented N-S. Even if it is considered a deep lake, having some lake sections with more than 3 m depth, the water level of the lake ends decreases dramatically presenting values of 100 cm depth or even less than that. Belciug Lake (110 ha) is located in the lower marine delta plain, namely in the southern part of the last meander of the Sf. Gheorghe branch (Fig. 1). Belciug Lake is a protected area of national interest listed as IUCN Category I (strict nature reserve of mixed type) by the International Union for Conservation of Nature and Natural Resources (IUCN). Due to the poor connection with the Danube, the relative degree of isolation and great depth (5-6 m), the Belciug Lake represents a very favorable conservation habitat for many species of plants and animals.

2.2 Field Methods – Sampling Procedures

During autumn 2015 has been brought into attention a new approach of some particular lakes, namely the oxbow lakes that have not been studied lately. Fig. 2 includes the localization of the 30 sampling stations for water and sediments. The sampling period was defined by a cold and rainy specific autumn weather. During the sampling periods the lakes were quite filled with aquatic vegetation.

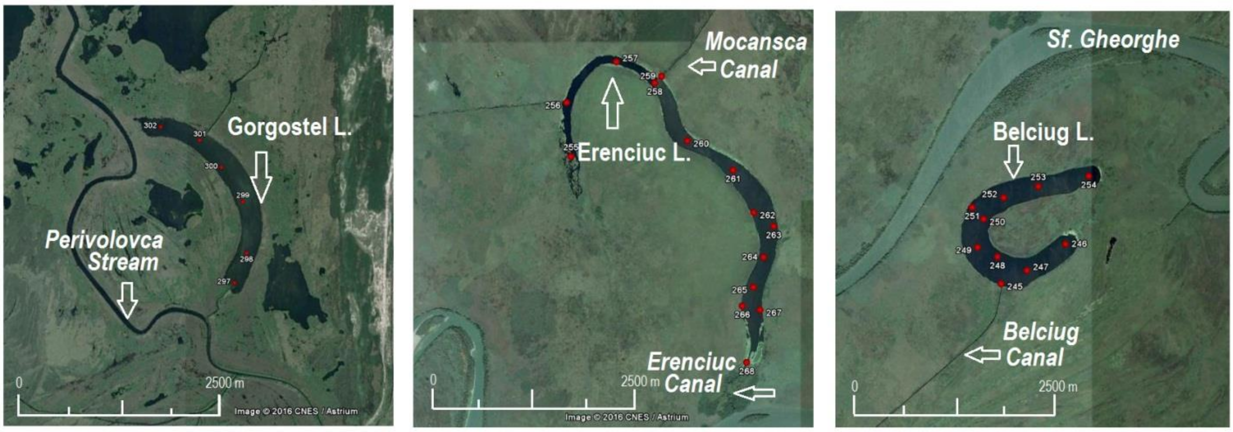

Figure 2. Location of the investigated lakes with sampling points

The investigation deals with the study of field observations and measurements, as well as the analysis and interpretation of some water surface environmental indicators as: depth (m), Secchi transparency (m), temperature (ºC), dissolved oxygen (mg/l), conductivity (µS/cm), total dissolved solids (mg/l), pH (units), redox potential (mV), turbidity (NTU), suspended solids (mg/l), nitrates (mg/l), nitrites (mg/l), orthophosphates (mg/l) and sulphates (mg/l). In equal measure, it was taken into consideration the percentage distribution of the physical sediment parameters as moisture and dry content, as well as the total organic matter, total carbonates and siliciclastic fraction, aiming to estimate the type of the recent sedimentary accumulations. The laboratory and field measurements applied on water and sediment samples were fulfilled aboard the "Istros" Research Vessel owned by the National Institute of Marine Geology and Geoecology – GeoEcoMar, Romania. The sampling procedures used the standard protocols. The surface water measurements of the selected physical and chemical parameters were done *in situ* at each sampling site using the WTW Multiline P4 Multiparameter, HACH 2100Q Portable Turbidimeter and HACH 5000-UV-Vis-Spectrophotometer. The grab sediments (0-20 cm) were manually sampled in each lake using a Van-Veen grab sampler, and the core sediments were gathered only from Erenciuc and Belciug lakes, using the Hydrobios Sediment corer type. In the laboratory, the sediment samples were analyzed for the percentage distribution of the main lithological components using the Loss of Ignition Method (Dean 1974; Heiri et al. 2001) based on the sequential heating of samples by high-temperature electric furnaces SNOL 8.2/1100ºC.

3 RESULTS AND DISCUSSIONS

The water and sediment analyses executed within study were aimed to establish if the water samples taken into consideration are within acceptable environmental standards and also to estimate the type of the recent sedimentary accumulations based on the percentage content of the sediment lithological components. The evaluation of the water analysis results was linked to the Normative 161/2006 - Standard on surface water quality classification for determination of the ecological status of Water bodies, Annex C-Elements and physico-chemical quality standards in water, and Annex D-Microbiology Quality Elements.

3.1 Water Analyses

A synthesis of the physico-chemical characteristics of the surface water samples collected from the investigated lakes is depicted below. The Table 1 contains the results expressed as the minimal, maximal and average values of the physico-chemical parameters of the water samples.

Table 1. A synopsis of the physico-chemical parameters of the lake surface water samples

GORGOSTEL Lake	The physico-chemical parameters					
Value	***Depth (m)***	***Secchi (m)***	***O2 (mg/l)***	***O2 (%)***	***Temp. (ºC)***	***CND (µS/cm)***
min	1.2	0.35	10.56	105.4	12.7	393
max	2.4	0.5	13.12	122	15.4	444
mean	1.75±0.48	0.46±0.07	12.37±0.91	117.43±6.07	13.62±1.01	406.17±19.91
Value	***TDS (mg/l)***	***pH (units)***	***Eh (mV)***	***Turb (NTU)***	***SS (mg/l)***	***$N\text{-}NO_3^-$ (mg/l)***
min	196.5	7.91	-	9,26	14	0.02
max	222	8.3	-	24,2	24	0.24
mean	203.08±9.96	8.15±0.13	-	18.65±0.18	20.67±5.77	0.09±0.13
Value	***$N\text{-}NO_2^-$ (mg/l)***		***$P\text{-}PO_4^{3-}$(mg/l)***		***SO_4^{2-}(mg/l)***	
min	0.012		0.12		23	
max	0.043		1.37		42	
mean	0.02±0.02		0.73±0.63		30.00±10.44	

ERENCIUC Lake	The physico-chemical parameters					
Value	***Depth (m)***	***Secchi (m)***	***O2 (mg/l)***	***O2 (%)***	***Temp. (ºC)***	***CND(µS/cm)***
min	1	0,4	2.38	23.9	13.2	383
max	2.7	1	5.03	48.8	17.1	446
mean	2.26±0.44	0.63±0.15	3.37±1.01	35.23±9.59	15±0.95	407.62±23.30
Value	***TDS (mg/l)***	***pH (units)***	***Eh (mV)***	***Turb (NTU)***	***SS (mg/l)***	***$N\text{-}NO_3^-$ (mg/l)***
min	191.5	7.7	-14	4.72	10	0.01
max	225.5	9.04	-3	19.4	28	0.32
mean	205.36±12.61	8.33±0.42	-8.33±5.51	12.54±7.39	20.67±9.45	0.12±0.18
Value	***$N\text{-}NO_2^-$ (mg/l)***		***$P\text{-}PO_4^{3-}$(mg/l)***		***SO_4^{2-}(mg/l)***	
min	0.007		1.27		24	
max	0.031		1.943		42	
mean	0.02±0.01		1.65±0.34		31.33±9.45	

BELCIUG Lake	The physico-chemical parameters					
Value	***Depth (m)***	***Secchi (m)***	***O2 (mg/l)***	***O2 (%)***	***Temp. (ºC)***	***CND(µS/cm)***
min	2.7	1	3.73	38.2	17.2	440
max	8.7	1.2	6.3	65	17.7	470
mean	5.92±2.19	1.02±0.06	5.29±0.83	54.47±8.61	17.47±0.19	445.1±8.90
Value	***TDS (mg/l)***	***pH (units)***	***Eh (mV)***	***Turb (NTU)***	***SS (mg/l)***	***$N\text{-}NO_3^-$ (mg/l)***
min	220	7.05	-9	6.81	12	0.02
max	235	8.3	-8	8.8	15	0.02
mean	222.6±4.45	8.03±0.37	-8.67±0.58	7.62±1.05	13.67±1.53	0.02
Value	***$N\text{-}NO_2^-$ (mg/l)***		***$P\text{-}PO_4^{3-}$(mg/l)***		***SO_4^{2-}(mg/l)***	
min	0.007		0.166		22	
max	0.009		1.416		24	
mean	0.01		0.58±0.72		22.67±1.15	

The analytical data of different physico-chemical parameters are found to be generally in accordance with environmental regulations. The average temperature distribution during the sampling campaigns was consistent with the expected seasonal variations. The water depth and the Secchi transparency varied in function of the sampling site locations. The greatest depth of 8.7 m was found in the Belciug Lake; the other lakes have an average depth of 1.75 m (Gorgostel Lake) and respectively of 2.26 m (Erenciuc Lake). The oxygen content throughout the all investigated sampling sites were above or below the maximum content level required by the environmental standard. Low levels of the oxygen content were found in some sectors of Erenciuc (2.38 mg/l) and Belciug (3.73 mg/l) lakes (Fig. 3). These results could be linked with the excessive algae growth, die-off and decomposition of submerged plants - a complex process that consumes the amounts of dissolved oxygen available in lakes. The results of the electrical conductivity and the total dissolved solids levels were found in the range established by the environmental standard. As shown in the Table 1, the pH results fluctuate within the investigated lakes (Fig. 3), being registered normal values that grow gradually, thus conferring a slightly alkaline character of the water.

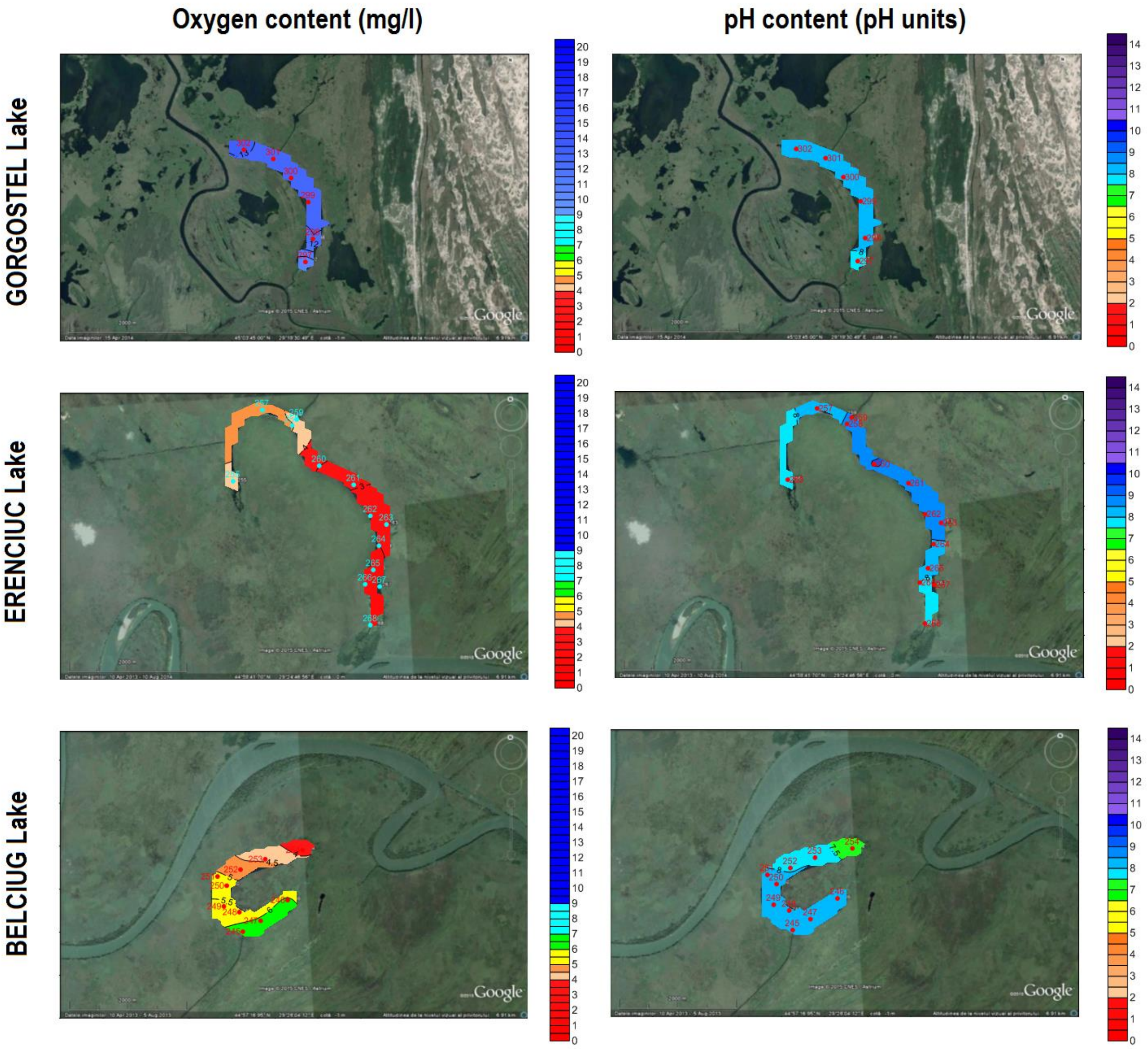

Figure 3. Areal distribution of dissolved oxygen content and pH, characterizing the surface waters in the investigated lakes

The registered values of the oxidation-reduction potential of the investigated surface waters present the following variations: from -14 mV to -3 mV, in Erenciuc L., and from -9 mV to -8 mV, in Belciug L., suggesting possibly that reducing conditions are prevalent in water lakes. The relatively higher values of turbidity noticed in the surface waters could be linked by phytoplankton, organism activity, organic detritus, re-suspended bottom sediments etc. The nitrites ($N\text{-}NO_2^-$) and nitrates ($N\text{-}NO_3^-$) concentrations also agreed, for all samples, with the environmental standard (Normative 161/2006). As regards the ortophosphates ($P\text{-}PO_4^{3-}$), there have been noticed some samples with concentrations above the maximum recommended by environmental standard. Not being excluded the idea of upstream significant industrial and domestic discharges, most likely, the increased levels of phosphates registered within the investigated lakes are of organic origin (manure waste from various species of birds and/or aquatic organisms). The sulfate levels were found in the range established by the environmental regulations. The results expressed as an average value of the water quality parameters varied conforming to the local conditions, sampling stations, seasonal changes in water budget throughput lakes etc.

3.2 Sediment Analyses

With the aim of evaluating the main lithological components present in the lacustrine sediments and relating them to the source of recent accumulation, it can be appreciated that the investigated lakes are mainly supplied with autochthonous material derived from biological and microbiological production and decomposition processes occurred within the lakes.

Table 2. A synopsis of the main lithological results tested on the grab and core sediment samples

GRAB SEDIMENT SAMPLES						
GORGOSTEL Lake	***Value***	***Water content (%)***	***Dry matter (%)***	***Total organic matter (%)***	***Total carbonates (%)***	***Siliciclastic fraction (%)***
	min	12.49	76.41	63.79	1.52	10.41
	max	23.59	87.51	87.87	2.62	33.59
	mean	16.14±3.97	83.86±3.97	80.39±9.52	1.97±0.38	17.64±9.21
ERENCIUC Lake	***Value***	***Water content (%)***	***Dry matter (%)***	***Total organic matter (%)***	***Total carbonates (%)***	***Siliciclastic fraction (%)***
	min	7.85	86.27	52.25	0.25	2.22
	max	13.73	92.15	97.53	3.74	44.94
	mean	10.74±1.55	89.26±1.55	83.14±10.25	1.87±0.88	14.99±9.76
BELCIUG Lake	***Value***	***Water content (%)***	***Dry matter (%)***	***Total organic matter (%)***	***Total carbonates (%)***	***Siliciclastic fraction (%)***
	min	9.81	82.27	72.90	0.66	2.69
	max	17.73	90.19	96.66	8.62	22.35
	mean	13.89±2.86	86.11±2.86	84.11±6.82	2.20±2.44	13.69±5.35
CORE SEDIMENT SAMPLES						
ERENCIUC Lake (0-33 cm)	***Value***	***Water content (%)***	***Dry matter (%)***	***Total organic matter (%)***	***Total carbonates (%)***	***Siliciclastic fraction (%)***
	min	26.43	24.12	43.33	1.98	16.40
	max	75.88	73.57	81.62	3.95	53.58
	mean	42.87±14.27	57.13±14.27	68.58±10.79	2.91±0.52	28.51±10.56
BELCIUG Lake (0-70 cm)	***Value***	***Water content (%)***	***Dry matter (%)***	***Total organic matter (%)***	***Total carbonates (%)***	***Siliciclastic fraction (%)***
	min	26.43	24.12	43.33	1.98	16.40
	max	75.88	73.57	81.62	3.95	53.58
	mean	42.87±14.27	57.13±14.27	68.58±10.79	2.91±0.52	28.51±10.56

The identification of these increased levels of total organic matter present in the majority of the samples is consistent with the predominant sediment types in the investigated perimeters. These sediments have a high content of the total organic matter, a low content of carbonates, and siliciclastic fraction, respectively. The siliciclastic fraction content is inversely correlated with the total organic matter content. According to the Fig. 4, from the three studied lakes, it can be noticed that the total organic matter is prevalent in the majority of sampling sites. This study comprises the analyses of two short cores collected from Erenciuc and Belciug lakes, aiming to provide some basic data related to past and recent environmental changes. The percentage distribution of the short cores sediment parameters is included in the Table 2. The total organic matter presents slight variations; in general, higher values that gradually decrease as it descend deep down to the end of the core. The percentage of the total carbonate contents show lower values (Fig. 5). The siliciclastic fraction content shows relatively low values versus the total organic matter content which is inversely correlated.

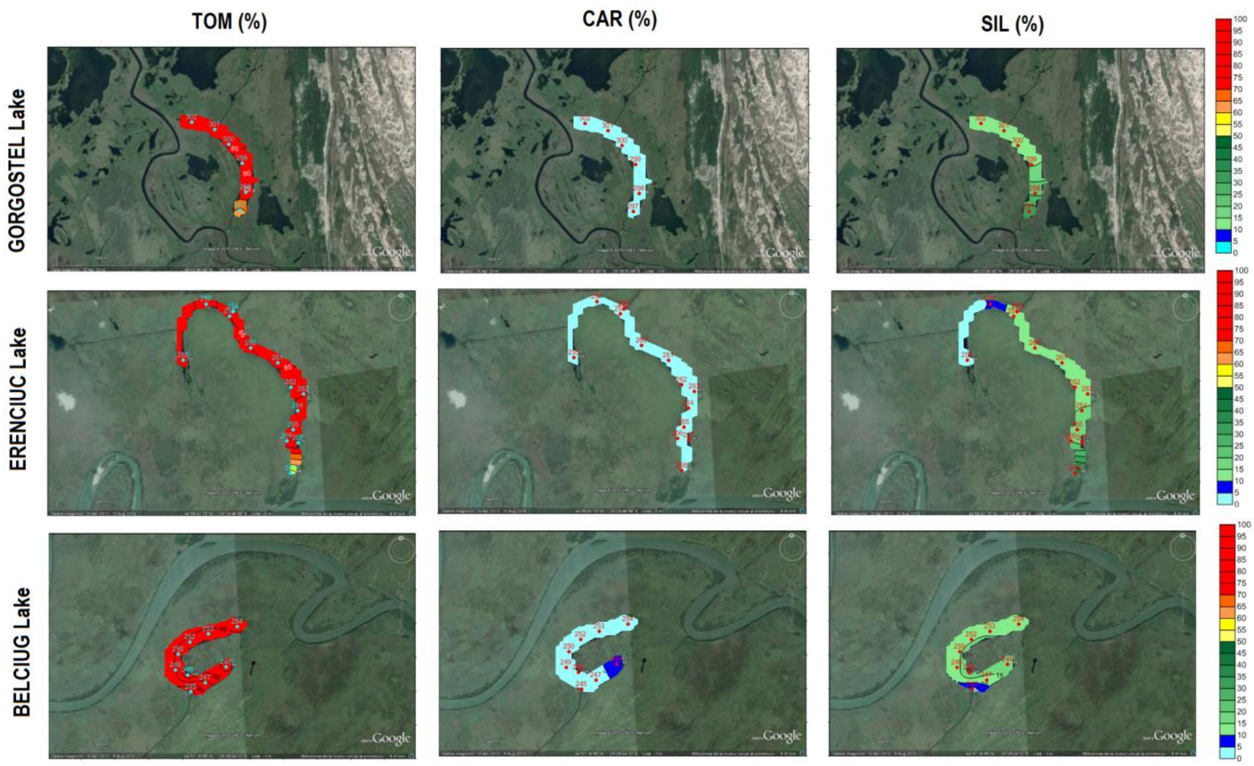

Figure 4. The areal distribution and percentage concentrations of the investigated parameters (total organic matter – TOM %, total carbonates – CAR % and siliciclastic fraction – SIL %) in grab sediment samples

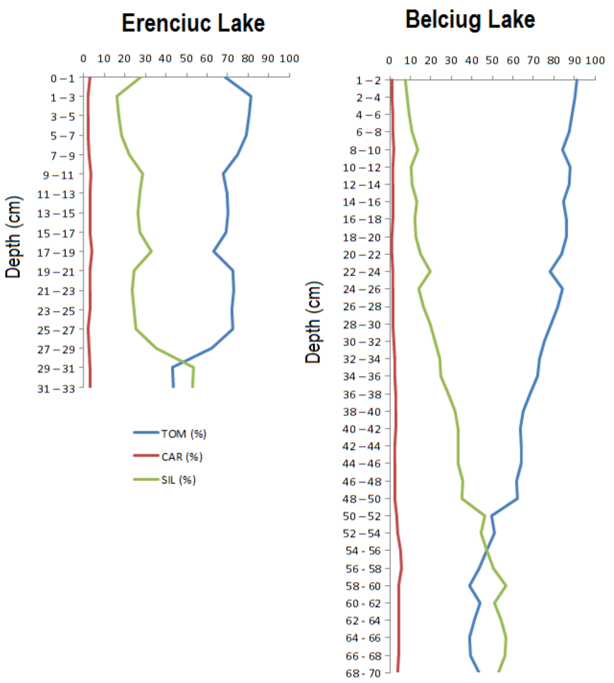

Figure 5. The vertical distribution and percentage concentrations of the investigated parameters (Total organic matter – TOM %, total carbonates – CAR % and siliciclastic fraction – SIL %) in core sediments

The accumulation of the total organic matter may have advantaged by a high level of primary activity, abundant lacustrine vegetation (phytoplankton, macrophytes), high sedimentation rate and low water dynamics thus justifying the huge amount of the total organic matter in these sediments. The presence of total carbonates may have related to the authigenic origin (chemical precipitation, recristalization, the existence of autochthonous or upstream allochthonous carbonaceous skeletal parts). The siliciclastic fraction represents moderate percentage content from the entire mass of the sediment, being inversely correlated with the total organic matter content.

4 CONCLUSIONS

The analyses of water samples from the three investigated oxbow lakes, namely, Gorgostel, Erenciuc and Belciug, generally show good environmental conditions relative to the different physico-chemical parameters, even if, incidentally, there have been noticed some inaccuracies in some sectors of the lakes. It is important to note that the analyses of water submit an instantaneous image of the lake's environmental circumstances at the moment of sampling.

Regarding the sediments, the percentage distribution results of the physical sediment parameters as moisture and dry content, as well as total organic matter, total carbonates and siliciclastic fraction, also fluctuates in function of the specific local conditions of the studied areas. The main findings did not notify major differences between the investigated areas.

In conclusion, this study report that the water quality investigated in these particular lakes is in a sustainable condition. The particular environmental conditions of lakes speed up the accumulation of the total organic matter that is assured of autochthonous source. The acquired results could be base for future studies concerning the oxbow lakes evolution.

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