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ASSESSMENT OF THE SURFACE WATER QUALITY DATA COLLECTED SEASONALLY AT THE DANUBE RIVER BIFURCATIONS (CEATAL IZMAIL AND CEATAL SF. GHEORGHE)

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Abstract

This study was carried out in the Danube Delta, at Ceatal Izmail and Ceatal Sfântu Gheorghe. The investigated sectors are of great importance, being essential key points related to the hydrological connectivity between the Danube River distributary branches and interdistributary channels, streams, and lakes of the Danube Delta. Thereby, six stations were selected to provide seasonal water quality data, collected biannually, from 2018 to 2023, in different hydrodynamic conditions (high and low waters). To assess the conditions of the investigated surface waters, several physical in-situ measurements (T, pH, DO, EC, TDS, Transp.) were taken at all sampling locations. Additionally, water samples were collected for laboratory analysis (N-NH_4^+, N-NO_2^-, N-NO_3^-, P-PO_4^{3-}, Chla, SiO_2, TOC, SO_4^{2-}, Turb., TSS, ORP). The criteria used to assess the water quality in the investigated sites include the current Romanian national legislation (Ord. 161/2006) and other international environmental standards. Most of the investigated physical-chemical parameters were in line with correlated criteria, and only incidentally, the objectives were exceeded at single or multiple locations. According to this assessment, permanent monitoring of water quality is mandatory at these important hydrological nodes, by analyzing the status and trends in physical and chemical characteristics of the surface water environment.

Key words: *ecosystems, environment, physical-chemical parameters, seasonal, water quality.*

INTRODUCTION

Nowadays, water pollution is a general concern worldwide. Preserving surface water quality is essential for daily demand everywhere. The freshwater which is stored in rivers, lakes, reservoirs, creeks, and streams, represents the major source of water for the human population, animal and plant communities, as well as for irrigation water demands and other socio-economic requirements.

Since the beginning of industrialization and the expansion of modern civilization, the Danube River water quality has been persistently declining because of anthropogenic inputs and the discharging of untreated or poorly treated sewages (Ilie et al., 2014; Simionov et al., 2020). Even if, lately, a series of measures have been taken regarding the environmental conservation and preservation of surface waters (EU-WFD, 2000), the river is still subject to natural and anthropogenic pressures due to its function as an environmental resource and economic potential, such as navigable transport, water regulation, commercial fishing, recreational activities etc. (Gasparotti, 2014). In addition, the consequences of the Iron Gate dam constructions (1972 and 1985), hydro-technical works, water abstractions, and associated impoundments, regulations etc. (Panin et al., 1999), resulted in considerable changes in physical, chemical, and biological characteristics of the downstream Danube River water (Gasparotti et al., 2013).

The Danube is one of the world's most international rivers and is regarded as a pan-European river, not only because of its length and large drainage basin area, but especially due to its pan-European character in socio-economic and cultural aspects (Padlo et al., 2021).

The Danube River is the second-longest river in Europe after the Volga (in Russia), regarding length (2857 km) and area (801463 km^2), shaping one of the most important and large European water system consisting of the Danube River - Danube Delta - Black Sea (Panin et al., 2016; Calmuc et al., 2023).

The river is subdivided into three main sections: the Upper Danube (1060 km), the Middle Danube (725 km), and the Lower Danube (1075 km). The Lower Danube (1075 km) represents a natural border between Romania and states such as Serbia, Bulgaria, Ukraine, and the Republic of Moldova (Gâştescu & Ţuchiu, 2012). Before reaching the Black Sea, the Danube River splits into three main branches: Chilia to the North (with a length of 104 km, transporting 60% of the Danube's flow), Sulina in the middle (with a length of 71 km and carrying 18% of the Danube's flow) and Sf. Gheorghe in the South (with a length of 112 km and 22% of the Danube's flow). The areas between these branches shape the distinct specific environments of the Danube Delta.

The Danube's alluvial inputs, distributed by the three branches, loaded with solid particulate material and other associated contaminants, is considerably the main source of the local potential pollution, being currently accountable for the environmental impairments within the river and the north-western region of the Black Sea (Păun et al., 2017).

Due to its large catchment and the anthropic pressures, the Danube water is affected by pollution from multiple sources (Jitar et al., 2015; Pavlović et al., 2016; Simionov et al., 2021). As mentioned before, the Danube River water quality is vulnerable to contamination as a consequence of anthropogenic inputs such as discharges of industrial and agricultural effluents or untreated wastewaters which can have both allochthonous, as well as autochthonous origin. These potential contaminants may lead to severe changes in the physical-chemical and biological parameters not only of the Danube River but also of the Danube Delta ecosystems. Maintaining good water quality and proper ecosystems is imperative for the favorable functioning of the Danube River Delta region (Kyle, 2006).

In this context, the purpose of the study was to assess the surface water quality at the Danube River bifurcations, i.e., *Ceatal Izmail* and *Ceatal Sf. Gheorghe*, the two main distribution nodes for water and sediment throughout the Danube Delta.

Regular water quality assessment of the Danube River, especially in these specific "key" locations is critical for sustaining viable water criteria for the unique aquatic biodiversity and migratory birds (Rose, 1992; Rose, 1993; Zöckler et al., 2003) as well as ecosystem services of the Danube Delta (Cazacu & Adamescu, 2017; Gómez-Baggethun et al., 2019; Lazăr et al., 2022). This study contributes to covering a gap in published data on water quality in these specific locations (Burt et al., 2013; Myroshnychenko et al., 2015; Chapman et al., 2016).

MATERIALS AND METHODS

Study area

This study was carried out at the main two bifurcations of the Danube River within its Delta, i.e., *Ceatal Izmail* and *Ceatal Sf. Gheorghe* (Figure 1). At the first bifurcation of the Delta - *Ceatal Izmail*, the Danube River splits into two distributaries: Chilia (the northern Arm) and Tulcea (the southern Arm). Branching in the right direction at *Ceatal Izmail* (Mile 43), the Tulcea Arm extends farther south to 17 km to the second bifurcation at *Ceatal Sf. Gheorghe* (Mile 34).

Here, the Tulcea Arm separates into two main branches: Sulina Arm (on the left) and Sf. Gheorghe Arm (on the right) (Duțu et al., 2022). The investigated sectors i.e., *Ceatal Izmail* and *Ceatal Sf. Gheorghe,* are of great importance, being essential key points related to the hydrological connectivity between the Danube River distributary branches and interdistributary channels, streams and lakes of the delta. As well, these bifurcations are characterized as very dynamic hydro morphological areas.

The purpose of the investigations was to emphasize the potential impact on the investigated ecosystems, due to the surplus of available contaminants that comes from different upstream and local anthropogenic activities, considering that the pollution point sources leakages are increased in the lower sector contrary to the upper Danube area (Gasparotti, 2014).

Sample collection

Distinct control sections (sampling stations) were selected (Figure 1) to provide seasonal data on the dynamics of different physical-chemical environmental indicators. The sampling activities occurred at the R/V "Istros" of the National Institute for Research and Development of Marine Geology and Geo-ecology-GeoEcoMar, Romania.

An overall number of 57 water samples were collected seasonally, from 2018 to 2023, in different hydrodynamic conditions (high and low Danube levels) (Figure 2).

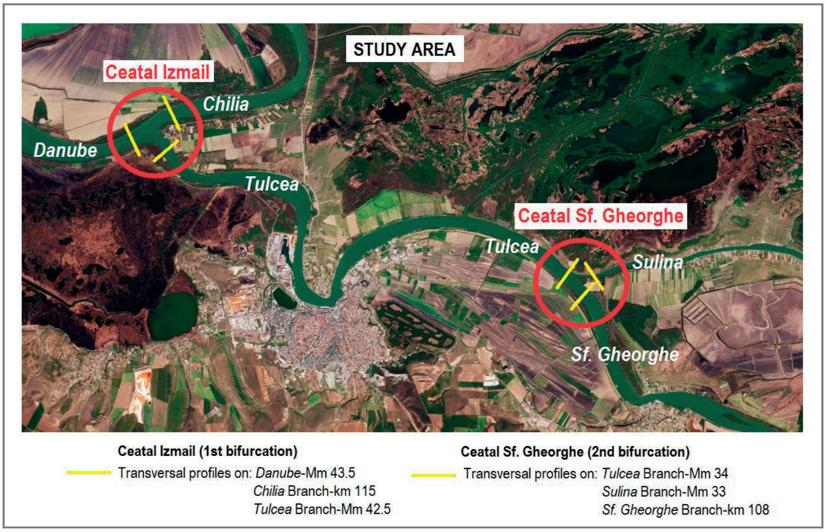

Figure 1. Map of the Danube River bifurcations (Base map source: https://www.esa.int/)

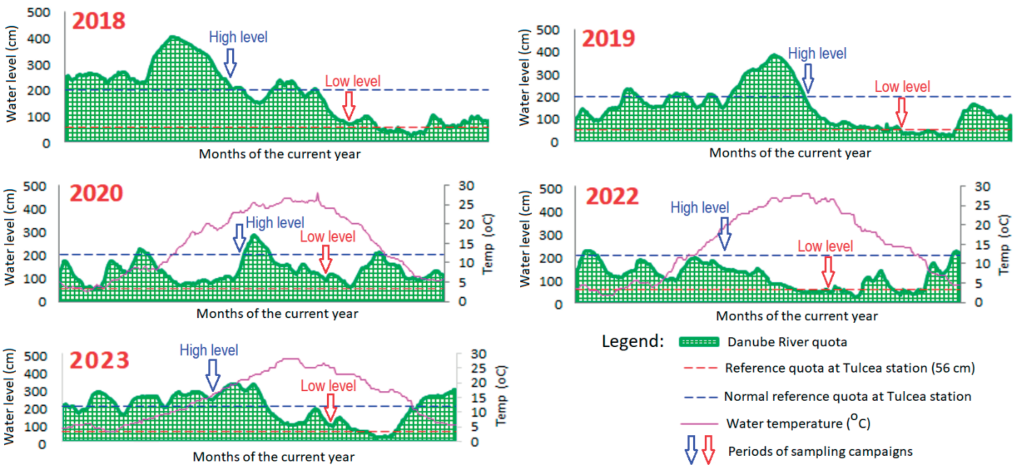

Figure 2. Danube River flow variations recorded at the Tulcea Port (https://www.afdj.ro/ro/cotele-dunarii)

The periods of sampling campaigns with wet season conditions (seasonal rains) and high-water Danube levels were: *May 2018* (04.05-13.05), *July 2019* (01.07-14.07), *June 2020* (15.06-28.06), *May 2022* (09.05-17.05) and *May 2023* (16.05-23.05). Then, the periods of sampling campaigns with dry season conditions (no significant rain recorded) and low-water Danube levels were: *August 2018* (08.08-27.08), *September 2019* (24.09-04.10), *August 2020* (25.08-05.09), *August 2022* (22.08-31.08) and *September 2023* (06.09-15.09).

The exact location of the stations was recorded every single time, and the samples were gathered from the middle of each distributary, at a depth of 0.5 m.

From the *Ceatal Izmail bifurcation,* the following samples were gathered as: *Dunărea-Mm 43.5* (*wet season*: DD18-02, DD19-18, DD20-18, DD23-02; *dry season*: DD18-79,

DD19-119, DD20-101, DD22-67, DD23-97), *Chilia-km 115* (*wet season*: DD18-05, DD19-15, DD20-15, DD23-05; *dry season*: DD18-86, DD19-122, DD20-104, DD22-70, DD23-100) and *Tulcea-Mm 42.5* (*wet season*: DD18-08, DD19-21, DD20-21, DD23-08; *dry season*: DD18-82, DD19-125, DD20-110, DD22-73, DD23-104). From the *Sf. Gheorghe bifurcation,* the following samples were collected as: *Tulcea-Mm 34* (*wet season*: DD18-14, DD19-27, DD20-27, DD22-05, DD23-14; *dry season*: DD18-132, DD19-131, DD20-113, DD22-79, DD23-109), *Sulina-Mm 33* (*wet season*: DD18-17, DD19-29, DD20-32, DD22-07, DD23-16; *dry season:* DD18-135, DD19-133, DD20-115, DD22-81, DD23-111) and *Sf Gheorghe-Km 108* (*wet season*: DD18-11, DD19-31, DD20-30, DD22-02, DD23-11; *dry season:* DD18-138, DD19-135, DD20-117, DD22-76, DD23-106). It is worth mentioning that navigable waterways are expressed in nautical miles (i.e. Mm), and natural courses in km.

Parameters such as temperature, pH, dissolved oxygen, electrical conductivity and total dissolved solids were acquired *in situ*, at each sampling location, using the WTW Multiparameter Field Meter-3630 IDS. Subsequently, laboratory analysis was achieved to identify the contents of ammonium, nitrite, nitrate, phosphate, chlorophyll "a", silica, total organic carbon, sulfates, turbidity, total suspended solids, water transparency and oxidation-reduction potential using a Hach-DR6000 UV-VIS Spectrophotometer and a Hach-2100 Portable Turbidimeter. The analysis protocol is established according to standard methodologies of the laboratories of NIRD GeoEcoMar.

RESULTS AND DISCUSSIONS

Throughout time, the Danube River aroused interest in the scientific community that has been manifested by different investigations and research studies under several aspects, such as the environmental impacts of hydroelectric power (Panin & Jipa, 2002; Vukovic at al., 2014; Habersack & Bradley, 2022), the significant impact of anthropogenic organic and inorganic substances (Cozzi et al., 2019; Mănoiu & Crăciun, 2021; Lazăr et al., 2024), the impacts of the heavy metals (Vignati et al., 2013; Rico et al., 2016; Saeed et al., 2023) etc. Anywise, there are not many environmental quality evaluations strictly dedicated to *Ceatal Izmail* and *Ceatal Sf. Gheorghe*. Taking into account the multitude of anthropogenic and natural factors that can contribute to Danube River water degradation, a first step within this study was made in the sense of the investigation of some selected physical-chemical parameters at the two bifurcations. So, this paper focused on assessing the physical-chemical parameters impacting water quality, and the seasonal, temporal and spatial variations of water quality in these Danube River's sections.

The results acquired within this study may improve the available water-quality database with relevant information in terms of the Water Framework Directive guidelines (EU-WFD, 2000) by combining water-quality data from multiple sources. The EU-WFD instructions, stipulate EU countries to implement water quality no less than the category “good status” in rivers, lakes, groundwater, estuaries and coastal waters, by 2027 at the latest.

The obtained results and interpretations were related to the current national legislation (Order 161/2006), in addition to other international reference standards referring to the quality classification of surface water.

Generally, the average values of data sets related to the physical-chemical parameters investigated in sampling points at *Ceatal Izmail bifurcation* (Danube-Mm 43.5, Chilia-Km 115, Tulcea-Mm 42.5) and *Ceatal Sf. Gheorghe bifurcation* (Tulcea-Mm 34, Sulina-Mm 33, Sf. Gheorghe-Km 108) are relatively good. Generally speaking, no critical increments/abatements were noticed, apart from some specific cases that will be discussed hereinafter.

The variations (the minimum, maximum and average values) of the considered physical-chemical parameters between sampling stations are presented in Table 1 and Table 2.

Water temperature (ºC), water reaction levels (pH units) and dissolved oxygen contents (mg O_2/L) did not register significant differences. The water temperature's fluctuations were mainly related to the evolution of air temperature trends attributable to climatic seasons (www.accuweather.com/ro/) and the dynamic action of the wind. Consequently, significant differences between upstream (*Ceatal Izmail*) and downstream (*Ceatal Sf. Gheorghe*) were not registered in the investigated sampling points (Table 1) neither seasonal nor annual.

Regarding the reaction of water (pH units), it was noticed that the slightly alkaline pH values (Table 1) have the largest preponderance (Order 161/2006). Transitional waters (rivers, lakes etc.) generally range between acidic (5) and alkaline (9) on the pH scale, cumulating the results of diverse circumstances (microbial activity, microbial sulfate reduction, ammonification, water evaporation closely related to high contents of sodium and magnesium carbonates (Grant, 2004). Accordingly, there is no evident sign of acidity or alkalinity in the upstream (*Ceatal Izmail*) and downstream (*Ceatal Sf. Gheorghe*) probed waters, neither seasonal nor annual (Figure 3).

Table 1. Synthesis of the results obtained after the analysis of the parameters such as temperature, water reaction, dissolved oxygen, nutrients, chlorophyll and silica

Location		Value	T (ºC)	pH (unit)	DO₂ (mg O₂/L)	N-NH₄⁺ (mg/L)	N-NO₂⁻ (mg/L)	N-NO₃⁻ (mg/L)	P-PO₄³⁻ (mg/L)	Chla (µg/L)	SiO₂ (mg/L)
Ceatal Izmail	**Danube – Mm 43.5** *(n = 9)*	*Min.*	16.7	7.56	5.75	0.019	0.007	0.010	0.080	7.50	0.64
		Max.	27.7	8.56	9.26	0.064	0.035	0.330	1.666	24.06	5.23
		Average	23.62	8.03	7.68	0.041	0.013	0.134	0.350	14.42	2.74
	Chilia – Km 115 *(n = 9)*	*Min.*	17.3	7.24	5.72	0.003	0.007	0.050	0.053	8.06	1.08
		Max.	28.5	8.26	9.24	0.200	0.020	0.320	1.100	27.12	5.36
		Average	23.78	7.96	7.69	0.060	0.010	0.143	0.271	16.87	2.50
	Tulcea – Mm 42.5 *(n = 9)*	*Min.*	17.2	7.4	5.76	0.019	0.007	0.040	0.080	6.77	1.21
		Max.	28.2	8.24	9.53	0.080	0.023	0.320	1.660	28.60	4.72
		Average	23.49	7.96	7.69	0.040	0.012	0.144	0.439	13.58	2.69
Ceatal Sf Gheorghe	**Tulcea – Mm 34** *(n = 10)*	*Min.*	17.1	7.83	4.44	0.009	0.001	0.010	0.060	5.26	0.02
		Max.	26.8	8.2	9.39	0.070	0.032	0.330	1.650	20.39	5.03
		Average	22.74	8.03	7.41	0.030	0.011	0.144	0.458	11.41	2.50
	Sulina – Mm 33 *(n = 10)*	*Min.*	17.1	7.54	4.16	0.006	0.007	0.070	0.056	5.26	0.02
		Max.	27.1	8.27	9.36	0.110	0.025	0.300	1.850	20.67	4.80
		Average	22.80	7.99	7.32	0.045	0.010	0.142	0.711	12.11	2.44
	Sf. Gheorghe – Km 108 *(n = 10)*	*Min.*	17.5	7.35	4.73	0.008	0.008	0.050	0.046	3.91	0.75
		Max.	27	8.23	9.26	0.100	0.026	0.320	1.686	34.12	4.06
		Average	22.78	7.96	7.45	0.045	0.011	0.157	0.326	12.67	2.46

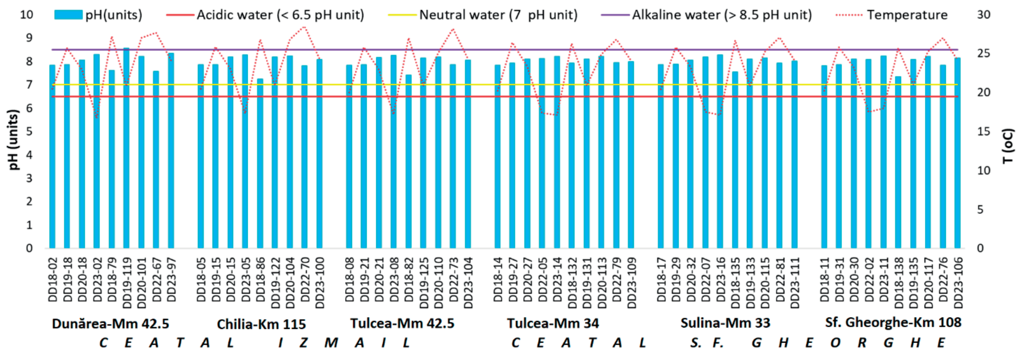

Figure 3. Seasonal and spatial variation of pH (water reaction) in investigated sites

The dissolved oxygen (DO) contents showed slight variations (Table 1) (Figure 4). Generally, the investigated sampling sites showed well-oxygenated surface waters (8 mgO₂/L), subsequently followed by moderate-oxygenated surface waters (5-7 mg O_2/L) (Order 161/2006), and poor-oxygenated surface waters (< 5 mg/L) (www.niwa.co.nz). Incidentally, poor-oxygenated surface waters were encountered in the year 2022 (in May) at *Ceatal Sf. Gheorghe* (Table 1), where some lower values were noticed, such as Tulcea-Mm 34 (DD22-05 = 4.4 mg O_2/L), Sulina-Mm 33 (DD22-07 = 4.16 mg O_2/L), and Sf. Gheorghe-Km 108 (DD22-02 = 4.73 mg O_2/L). The DO decreases could be related to local specific circumstances as a result of the increased organic load in the upstream urban section of the Danube River. Significant variations were not registered between the upstream and downstream sites (Table 1) neither seasonal nor annual, except *Ceatal Sf. Gheorghe* during 2022 (May).

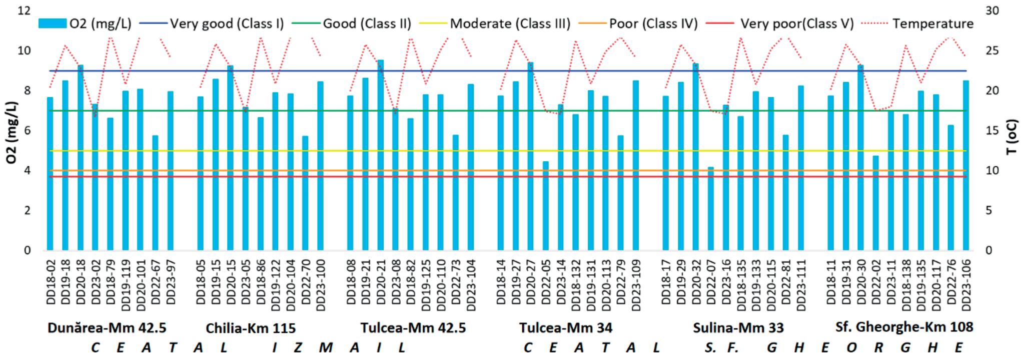

Figure 4. Seasonal and spatial variation of dissolved oxygen in investigated sites

In this study, the dynamic of the nutrient's regime (Nitrogen and Phosphorus compounds) showed an interesting situation and great variability. For instance, the concentration of different nitrogen compounds (such as ammonium, nitrite and nitrate) in the water samples did not show threatening changes.

The concentrations of ammonium ($N\text{-}NH_4^+$) showed lower values (Table 1), below the imposed limit (0.4 mg/L) settled for the first-class water quality (very good) (Order 161/2006).

In the case of nitrite-nitrogen ($N\text{-}NO_2^-$), a similar situation was noticed in the sense that the majority of values (Table 1) were included in the first-class water quality (very good) (0.01 mg/L) (Order 161/2006). However, during 2022 (August) two sampling sites detected values pertaining to the second-class water quality (good) (0.03 mg/L), such as Danube-Mm 43.5 (DD22-67 = 0.035 mg/L), Tulcea-Mm 34 (DD22-79 = 0.032 mg/L) (Figure 5).

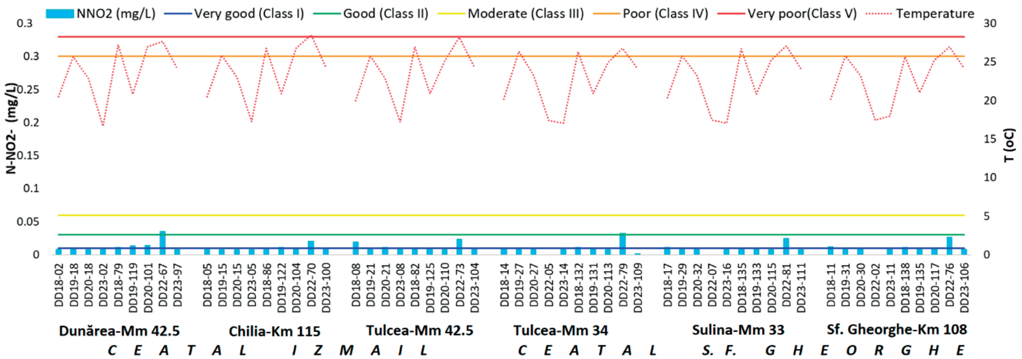

Figure 5. Seasonal and spatial variation of nitrite in investigated sites

In terms of nitrate-nitrogen ($N\text{-}NO_3^-$) very low values were noticed (Table 1), below the threshold (1 mg/L) settled for first-class quality (very good) (Order 161/2006).

Instead, the orthophosphate ($P\text{-}PO_4^{3-}$) contents showed great spatial, seasonal, and temporal variability (Table 1) (Figure 6). Values that cover the entire spectrum of all types of water quality categories were encountered, such as first-class water quality (very good) (0.1 mg/L), second-class water quality (good) (0.2 mg/L), third-class water quality (moderate) (0.4 mg/L), forth-class water quality (poor) (0.9 mg/L) and fifth-class water quality (very poor) (> 0.9 mg/L) (Order 161/2006). The values, varied randomly between upstream and downstream sites, from wet season to dry season, from one year to another year, all that independent of the spatial-temporal variation of the Danube water flow, so no relationship was found between them. Further seasonal analysis is required to untangle the influencing factors and spatial patterns of this variability.

Probably, the $P\text{-}PO_4^{3-}$ exceeding could be linked to local specific environments because of the increased contaminant load with phosphorus compounds (i.e., domestic effluents, agricultural inputs, industrial waste) in the upstream urban section of the Danube River. Additionally, natural sources may contribute to water contamination as a consequence of atmospheric deposition, natural decomposition of rocks and minerals, dissolution of soluble inorganic materials, decomposition of plant or animal biomass, re-sedimentation from the bottom substrate etc.

Given the large differences (one order of magnitude) between the highest (over 1 mg/L - class V) and the normal or low $P\text{-}PO_4^{3-}$ concentrations (class I and II) and the predominance of most high values to the Sulina Channel, another potential explanation for the large variability in nutrients concentration may be related to an overlooked local point source: enlarged contamination with residual water due to increased maritime navigation on the Danube. Among the three Danube's arms, Sulina Channel is the only one used for maritime commercial navigation with the end destination being the Brăila Harbor. Through their journey up or down between Sulina and Brăila, large commercial ships can often be found not only in designated harbors but also standing in line, anchored along the Danube's shore. This is especially true for the last years and mostly since the war in Ukraine started which caused a dramatic increase in the maritime navigation activities on the Danube. Such increased point-source pollution issues related to the intensified maritime traffic can affect the quality of the water for the Black Sea shore near the Sulina port area where nowadays, at any time somewhere between one and a few hundred ships, anchored in the port road, are awaiting long periods (even months) for their permission to navigate upstream on the river. However, the impact of increased navigation activities on the water quality of the Danube and the Black Sea has yet to be determined.

Generally, about the chlorophyll "a" (Chla - μg/L) content, lower values were obtained (Table 1), below the imposed limit (25 μg /L) settled for the first-class water quality (very good) (Order 161/2006). However, infrequently, three samples slightly exceeded this limit.

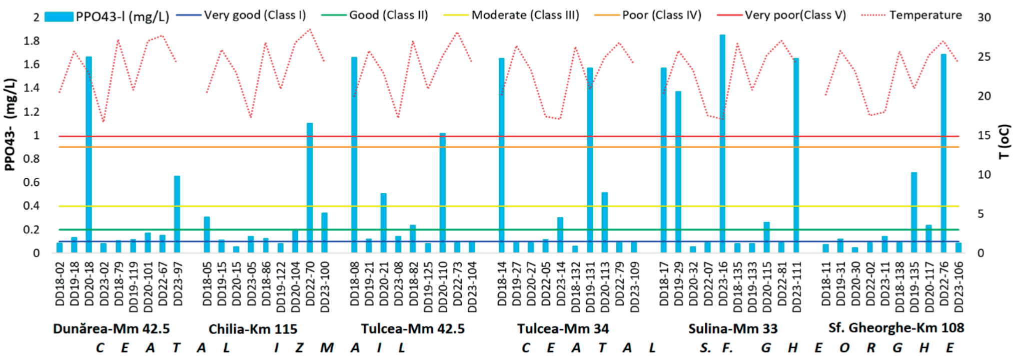

Figure 6. Seasonal and spatial variation of orthophosphates in investigated sites

The silica concentrations (SiO_2 - mg/L) varied more between the investigated stations (Table 1). Despite that, the values were low, below the conventional limit established for rivers and lakes (5-25 mg/L) (Chapman, 1996).

Under these circumstances, the concentration of nutrient compounds identified within this study (ammonium, nitrite, and nitrate), did not pose a serious stress on the aquatic biodiversity (variety of plants and animals) existent in the upstream (*Ceatal Izmail*) and downstream sites (*Ceatal Sf. Gheorghe*). Appropriately, the results obtained for chlorophyll "a" and silica content are not conducive to a phenomenon of excessive nutrient enrichment in the investigated freshwater samples.

As regards the orthophosphates, spatiotemporal variations were recorded, as well as some extreme values that were encountered randomly. In this context, it is recommended that a periodical monitoring program should be carried out, considering the impact of phosphates exceeding on aquatic environments (i.e., eutrophication, oxygen deficiency, and the reduction of biodiversity).

As concerns to total organic carbon (TOC - mg/L) levels, lower values were detected (Table 2).

Table 2. Synthesis of the results obtained after the analysis of the parameters such as total organic carbon, electrical conductivity, total dissolved solids, sulphates, turbidity, total suspended solids, transparency and oxidation-reduction potential

Location		Value	TOC (mg/L)	EC (µS/cm)	TDS (mg/L)	SO_4^{2-} (mg/L)	Turb. (mg/L)	TSS (mg/L)	Transp. (m)	ORP (mV)
Ceatal Izmail	**Danube – Mm 43.5** *(n = 9)*	*Min.*	2.27	345	173	24	7.93	9	0.15	-19
		Max.	9.20	425	213	37	57.2	52	1	80
		Average	4.43	386.63	192.31	30.56	23.80	27.89	0.54	25.71
	Chilia – Km 115 *(n = 9)*	*Min.*	1.97	345	173	26	15.5	14	0.1	-76
		Max.	24.90	420	210	45	56.5	70	1	92
		Average	7.95	390.50	194.19	32.00	30.37	33.11	0.52	17.50
	Tulcea – Mm 42.5 *(n = 9)*	*Min.*	1.98	345	173	27	9.41	11	0.2	-22
		Max.	11.10	417	209	33	47.5	232	1.1	74
		Average	5.17	385.63	191.75	29.33	22.31	48.33	0.52	23.38
Ceatal Sf Gheorghe	**Tulcea – Mm 34** *(n = 10)*	*Min.*	2.03	347	174	23	7.92	13	0.3	-22
		Max.	32.60	417	209	44	73.7	68	0.9	93
		Average	10.15	386.78	193.56	30.10	23.80	25.50	0.53	25.22
	Sulina – Mm 33 *(n = 10)*	*Min.*	1.87	348	174	24	8.81	13	0.15	-36
		Max.	22.40	417	209	34	51.5	60	0.7	90
		Average	9.15	388.22	194.22	29.00	24.23	27.50	0.48	25.56
	Sf. Gheorghe – Km 108 *(n = 10)*	*Min.*	2.05	347	174	23	7.55	11	0.15	-55
		Max.	22.90	417	209	49	69.7	69	0.8	94
		Average	8.53	386.78	193.56	30.70	22.88	24.70	0.48	24.67

The results did not overpass the typical limits of natural water variations (1-30 mg/L) (www.for.gov.bc.ca), except one sample collected during 2023 (May) from Tulcea-Mm 34 (DD23-14 = 32.6 mg/L) that could be related to local environmental environs (i.e., excessive amounts of organic load). Admittedly, there is no evident sign of potential organic contamination between upstream (*Ceatal Izmail*) and downstream sites (*Ceatal Sf. Gheorghe*), neither seasonal nor annual.

The data set results related to the electrical conductivity (EC) (µS/cm) (Figure 7), total dissolved solids (TDS) (mg/L), and sulfate levels (SO_4^{2-}) (mg/L) investigated at *Ceatal Izmail* and *Ceatal Sf. Gheorghe* revealed lower values (Table 2), below the threshold settled for the first-class quality (very good), as follows: EC (500 µS/cm) (Order 161/2006), TDS (0 - 1000 mg/L) (Lehr et al., 1980; De Zuane, 1997) and SO_4^{2-} (60 mg/L) (Order 161/2006). As a result, in terms of these parameters (i.e., EC, TDS and SO_4^{2-}) there is no evidence of poor water quality upstream (*Ceatal Izmail*) and downstream sites (*Ceatal Sf. Gheorghe*).

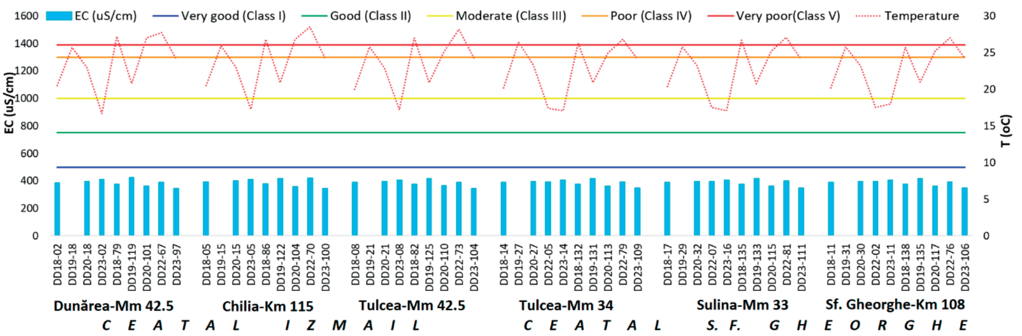

Figure 7. Seasonal and spatial variation of water electrical conductivity in investigated sites

In the case of turbidity, a small variation was recorded between the investigated stations (Table 2). Many values categorized the investigated water samples as low turbidity waters (< 10 NTU) and moderate turbidity waters (10 - 50 NTU) during the investigations (Figure 8). Despite that, the relatively highest values, which categorized the investigated water samples as high turbidity waters (50-100 NTU) were noticed during 2019 (July) at stations as Dunărea-Mm 43.5 (DD19-18 = 57.2 NTU), Chilia-Km 115 (DD19-15 = 56.5 NTU), Tulcea-Mm 34 (DD19-27 = 73.7 NTU), Sulina-Mm 33 (DD19-29 = 51.5 NTU), Sf. Gheorghe-Km 108 (DD19-31 = 69.7 NTU). These relatively higher values may result from several factors, such as the variation of Danube River water levels, disintegration and resuspension of bottom sediments, rapid algal bloom etc.

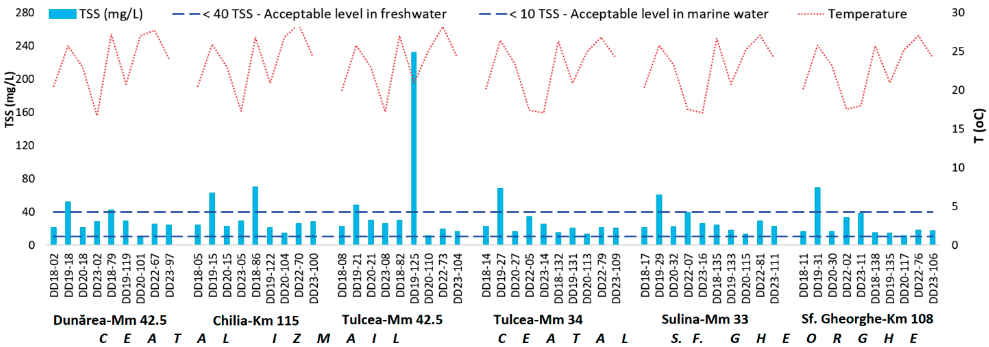

Figure 8. Seasonal and spatial variation of turbidity in investigated sites

Largely, in terms of the total suspended solids (TSS) (mg/L) it was noticed TSS values enclosed in the acceptable category of the freshwater environment (< 40 mg/L) (ANZECC 2000 Guidelines) (Table 2). Irregularly, relatively higher TSS contents (> 40 mg/L) were identified (Figure 9) during 2018 (August) at samplings as Chilia-Km 115 (DD18-86 = 70 mg/L), and 2019 (July) at sites as Dunărea-Mm 43.5 (DD19-18 = 52 mg/L), Chilia-Km 115 (DD19-15 = 63 mg/L), Tulcea-Mm 34 (DD19-27 = 68 mg/L), Sulina-Mm 33 (DD19-29 = 60 mg/L), Sf. Gheorghe-Km 108 (DD19-31 = 69 mg/L), including 2019 (September-October) at the station as Tulcea-Mm 42.5 (DD19-125 = 232 mg/L).

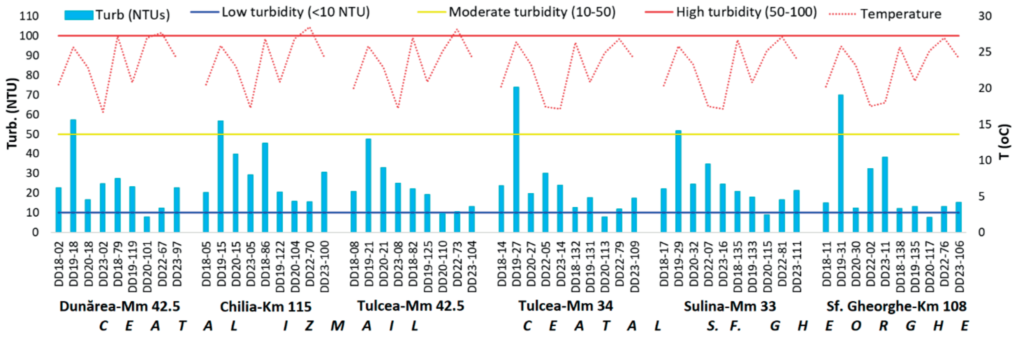

Figure 9. Seasonal and spatial variation of total suspended solids in investigated sites

The TSS higher concentrations are only recorded locally and may have several causes linked to both the natural variation of the suspended materials in the water (erosion of banks, content of organic matter) or anthropic (e.g. sources of pollution, waste, etc.).

On the subject of the oxidation-reduction potential, both positive and negative values were recorded (Table 2) with slight variations since the results were included in the broad range of natural waters from - 500 mV to + 700 mV (Chapman, 1996).

CONCLUSIONS

The results of this study present a general overview related to the status of the surface water quality investigated at the Danube River bifurcations (*Ceatal Izmail* and *Ceatal Sf. Gheorghe*). The physical-chemical conditions of these investigated key points are mainly controlled by the seasonal variations in the hydrological regime of the Danube River, as well as climatic changes and to a slight extent by the spatial variations. Most of the investigated environmental indicators showed very little seasonal fluctuations (i.e., water temperature, transparency, pH, dissolved oxygen, ammonium, nitrite, nitrate, chlorophyll "a", silica, total organic carbon, electrical conductivity, total dissolved solids and oxidation-reduction potential) which are included in the range of natural waters and are characteristic for the fluvial environments. Slight fluctuations and/or incidental exceeding of certain parameters from the trend lines (i.e., orthophosphates, turbidity and total suspended solids) were observed. These exceedances are probably related to the ongoing environmental circumstances (i.e., the impact of climate change and socio-economic development, that mask or enhance natural processes).

Conclusively, in terms of parameters such as pH, DO, $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, Chla, SiO_2, TOC, EC, TDS and ORP the investigated water samples indicate categories as very good and good water quality. But when it comes to $P\text{-}PO_4^{3-}$, turbidity and TSS, quite a few water samples indicate categories as moderate or poor water quality.

Even if, generally, biota have adapted to the variation in the physical-chemical variables, this study contributed with pieces of evidence that a continuous monitorization of multiple water quality environmental indicators is required for biodiversity conservation and ecosystem services in the Danube Delta.

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