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# PHYSICO-CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES FROM THE GORGOVA-UZLINA DEPRESSION AND THE IZMAIL AND SF. GHEORGHE CONFLUENCES (SEPTEMBER–OCTOBER 2024)

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***Abstract***

*The Danube Delta's ecosystems, encompassing riverine branches, lakes, and wetlands, face ecological pressures driven by natural and anthropogenic factors. This study evaluates the physico-chemical characteristics of surface water samples collected in September and October 2024 from 25 locations in the Gorgova-Uzlina Depression and 32 sites near the Izmail and Sf. Gheorghe confluences. Measurements were performed in situ using the EXO2 multiparameter probe (YSI, USA), which recorded parameters including temperature, pH, dissolved oxygen, chlorophyll "a," turbidity, electrical conductivity, and oxidation-reduction potential. Results indicate that most water samples fall within Class I and II of the Romanian water quality classification (Order 161/2006), reflecting good ecological status. Local variations in dissolved oxygen, turbidity, and chlorophyll "a" suggest potential ecological vulnerabilities, particularly in areas with elevated sediment loads. Conductivity and salinity values confirm the freshwater nature of the investigated sites. The findings highlight the importance of continuous monitoring to assess seasonal and anthropogenic influences on water quality and maintain the ecological integrity of the Danube Delta's aquatic ecosystems.*

***Key words**: Danube Delta; surface water quality; physico-chemical parameters.*

## INTRODUCTION

The Danube Delta, located in the southeastern part of Romania, is one of the most important ecosystems globally, hosting over 3500 plant species and approximately 1800 animal species (Gâștescu, 2009). With an area of approximately 5640 km², it represents a distinct geomorphological unit within the Danube-Danube Delta-Black Sea geosystem, acting as an ecological interface between the Danube River and the Black Sea basin. This strategic position allows the delta to function as a natural filter, influencing sedimentation processes by retaining solid materials and chemical substances transported by the river, either dissolved or associated with suspended particles (Cotet, 1960; Almazov et al., 1963; Oaie et al., 2015).

The complex hydrographic network of the delta includes natural and artificial channels, interconnected lakes and wetlands (Chiriac & Udrescu, 1965), significantly influencing sediment transport, nutrient dynamics, pollutant distribution and general water quality. These processes are determined by both natural factors and extensive anthropogenic interventions, which have substantially modified the hydrological and sedimentological dynamics within the delta (Isvoranu, 1979; Bondar & Panin, 2000; Panin, 2003; Romanescu, 2013). Anthropogenic activities, such as dam construction, hydrotechnical works (grooves, embankments, dikes, meander cuts) and canalization have a significant impact on sediment transport and deposition processes. Specifically, the construction of the Iron Gates I (1973) and Iron Gates II (1984) dams dramatically reduced downstream sediment discharge by approximately 25–30%, consequently affecting environmental conditions (Panin & Jipa, 2002; Habersack et al., 2016; Tiron Duțu et al. 2014; 2019; Kanownik et al., 2019).

Numerous studies have highlighted the importance of analysing water flow regimes, sediment transport, pollutant dynamics, flood impacts, trophic gradients, and nutrient cycling

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within the delta, given their profound effects on biodiversity, ecosystem health, navigation, and fishing activities (Calmuc et al., 2021a, 2021b). Accurate hydrochemical analyses require precise topographic data to characterize channel cross-sections and underwater terrain. Modern topographic equipment facilitates the collection of reliable data essential for studying these complex interactions. In addition, geochemical analyses play a crucial role in determining sediment provenance, weathering processes, diagenesis, anthropogenic impacts, and environmental risks (Wu et al., 2013; Najamuddin et al., 2016; Zhang et al., 2017; Bucșe et al., 2020; Teaca et al., 2020).

This study aims to analyse the physicochemical characteristics of surface waters in representative areas such as the Gorgova-Uzlina Depression and the confluence of Izmail and Sfântu Gheorghe during September and October 2024. The research will provide essential insights into the variability of hydrochemical parameters, identifying the influences of both natural factors and human activities on water quality and ecosystem dynamics in the Danube Delta.

The findings of this research have significant relevance for environmental management, conservation efforts, and policy formulation regarding the use and protection of water resources in the Danube Delta. By examining the physicochemical variability of surface waters and the specific impacts of anthropogenic activities, the study contributes crucial data for understanding and mitigating ecological risks (József et al., 2023; Kirschner et al., 2024). These insights can guide targeted interventions and inform sustainable management strategies aimed at conserving biodiversity, maintaining ecosystem functionality, and supporting socio-economic activities such as fishing, navigation, and tourism in this sensitive and internationally recognized region (Frîncu et al., 2021).

## MATERIALS AND METHODS

### *Study area*

The Gorgova-Uzlina Depression is located between the Sulina and Sfântu Gheorghe Arms, being influenced by the hydrographic system formed by the Litcov Canal, the Gârla Perivolovca and the Gorgova, Isacova and Uzlina Lakes. This region is characterized by variations in the hydrological regime, determined by morphological and hydrotechnical changes, which influence water circulation, sediment transport and water chemical quality. The closure and reopening of some channels (e.g. Gârla Filatului, Uzlina Canal) have modified the water and sediment supply over time, affecting the ecological balance of the lakes (Antipa, 1937; Driga, 2004). The confluences at Izmail and Sfântu Gheorghe are critical points for assessing water quality, being areas of mixing between river and lake waters, with intense sedimentation processes and changes in physico-chemical parameters (Poonam et al., 2013; Paun et al., 2017). These interactions are relevant for understanding the impact of the Danube on deltaic and coastal ecosystems (Gastescu & Stiuca, 2008; Dutu et al., 2023).

### *Methodology*

The assessment of surface water quality in the Gorgova-Uzlina lake complex was carried out through in situ measurements of key physicochemical parameters at 25 stations in lakes Uzlina, Isacova, Durnoliatca, Isaccel, Gorgova, Potcoava, Gorgovăț, Rădăcinoș and Rotund and in 32 stations from 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) in September and October 2024 (Figures 1 and 2).

Field analyses were performed using the multiparameter probe EXO 2 (YSI – USA) (Figure 3), equipped with sensors that collect water quality data through physical, optical and electrochemical detection methods (STAS 6323).

The determined parameters included:

Temperature (°C), pH (pH units), Turbidity (FNU), Total Dissolved Solids (TDS) (mg/L), Conductivity (µS/cm), Dissolved Oxygen (ODO mg/L), Oxygen Saturation (ODO%), Oxidation-Reduction Potential (ORP, mV), Salinity (PSU), Nitrate (NitraLED mg/L), Chlorophyll (RFU), Total Algal Content (TAL) – PC RFU.

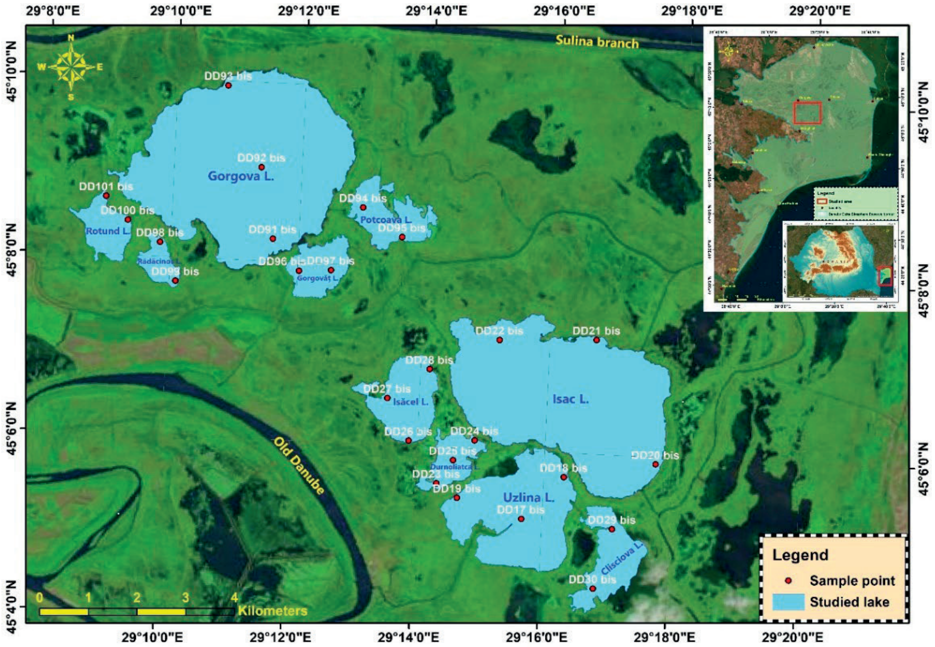



Figure 1. Sampling stations from Gorgova – Uzlina Complex

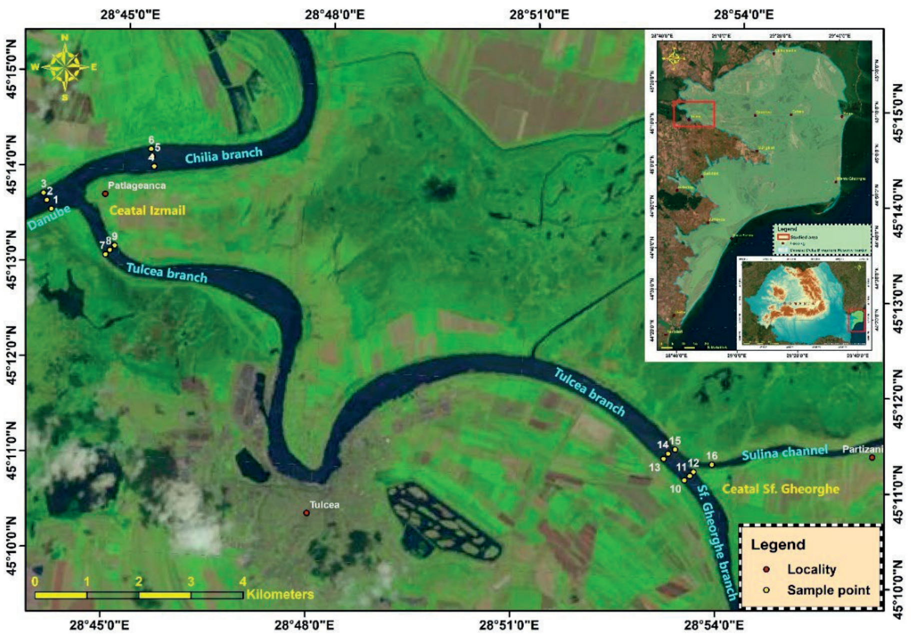



Figure 2. Sampling stations from the Ceatal Izmail and Ceatal Sf. Gheorghe

The water quality assessment was performed based on the classification provided by Order 161/2006, which defines five quality classes:

- Class I – Very good;
- Class II – Good;
- Class III – Moderate;
- Class IV – Poor;
- Class V – Bad.

In addition, reference standards from both national and international regulatory frameworks were considered to ensure a comprehensive assessment of water quality.


Figure 3. Multiparameter probe, model EX02

For a detailed analysis, both national and international water quality standards were applied. The assessment followed the European Union Water Framework Directive (WFD, 2000/60/EC), which sets requirements for managing aquatic resources to ensure a 'good' water quality status. In Romania, the evaluation was based on Regulation no. 161/2006 (Official Monitor of Romania, Part I, no. 511 bis), which outlines criteria for classifying surface water quality and ecological status, using parameters such as total dissolved solids (TDS) and turbidity (ISO 5667-5:2017). Physicochemical analyses were conducted in accordance with international standards, including SR EN ISO 5667-1:2023, SR EN ISO 10523:2012 (pH determination), and SR EN ISO 5814:2013 (dissolved oxygen measurement).

***Statistical analysis***

All statistical analyses were conducted using xlSTAT 7.5.2 software (Addinsoft, 2020) and Past 4 (https://past.en.lo4d.com/download). Pearson correlation was used to examine relationships between parameters.

## RESULTS AND DISCUSSIONS

The ecosystems of the Danube Delta – including the branches of the Danube River, channels, lakes, ponds and coastal ecosystems – are subject to ecological pressures resulting from natural factors such as hydrological fluctuations, sedimentation processes and climate variability, as well as anthropogenic activities, including agriculture, navigation, water pollution, fishing and infrastructure development (Cazacu & Adamescu, 2017; Chapter 10 Nutrients, 2025).

According to Annex XI of the WFD, the complexes of lotic ecosystems, represented by the Danube River and the Danube Delta, are part of the Pontic Ecoregion (12).

Based on to the updated Management Plan for the Danube River, the Danube Delta, the Dobrogea River Basin and Coastal Waters (2021), in conjunction with the details provided in sub-chapter 6.3, a total of 112 surface water bodies have been identified and classified into:

- 92 natural water bodies, including 20 rivers, 68 lakes, 2 transitional water bodies and 2 coastal water bodies;
- 15 heavily modified water bodies, comprising 3 rivers, 4 reservoirs, 6 heavily modified natural lakes and 2 coastal water bodies;
- 5 artificial water bodies (mainly river-type channels).

Of these 112 surface water bodies, 2 (approximately 1.78%) are classified as non-permanent, both belonging to the river category. The specific area of this study falls within the category RO15 (Danube – Isaccea – Danube Delta). Within the current management plan, natural water bodies have been identified for types RO15, RO19, RO06* and RO08*, while types RO13 and RO14 consist exclusively of heavily modified water bodies:

- RO06*: Lowland streams naturally devoid of fish fauna, usually characterised by intermittent flows, shallow depths and limited ecological complexity.
- RO08*: Similar to RO06*, these are also lowland streams without naturally occurring fish populations, frequently subject to dry periods and minimum water flow.
- RO13 (Danube River - Cazane - Călărași): A heavily modified river sector, significantly influenced by human activities such as navigation, river training and infrastructure development.
- RO14 (Danube River - Călărași - Isaccea): Another extensively modified section

of the Danube River, shaped by navigation channels, hydraulic engineering works and associated anthropogenic pressures.

- RO15 (Danube River - Isaccea - Danube Delta): Represents the lower section of the Danube, characterized by complex hydrological dynamics, high ecological diversity, significant sediment transport and natural interactions between fluvial and deltaic ecosystems.
- RO19: Non-permanent lowland streams, characterized by seasonal or intermittent flow regimes, which usually dry up periodically.

The values of the physicochemical parameters generally varied within the limits set by environmental standards, in particular national standards set by Romanian legislation (such as Order 161/2006), international guidelines and the criteria highlighted by the European Union Water Framework Directive (EU-WFD, 2000). The results obtained in this study contribute to improving the existing database on water quality by providing relevant and detailed information, aligned with the EU-WFD guidelines. The integration of data from multiple authorized sources, including national monitoring programmes, scientific studies and regulatory frameworks, ensures a complete and robust assessment of water quality. According to the EU-WFD provisions, European Union Member States must ensure that rivers, lakes, groundwater, estuaries and coastal waters achieve at least a “good” ecological status by 2027 at the latest. The results of the physicochemical determinations obtained at the sampling points are presented in Tables 1 and 2, indicating the minimum, maximum and average values (±standard deviation) for each analysed parameter.

Table 1. A synopsis of the physico-chemical parameters of water surface samples from Izmail and Sf. Gheorghe confluences

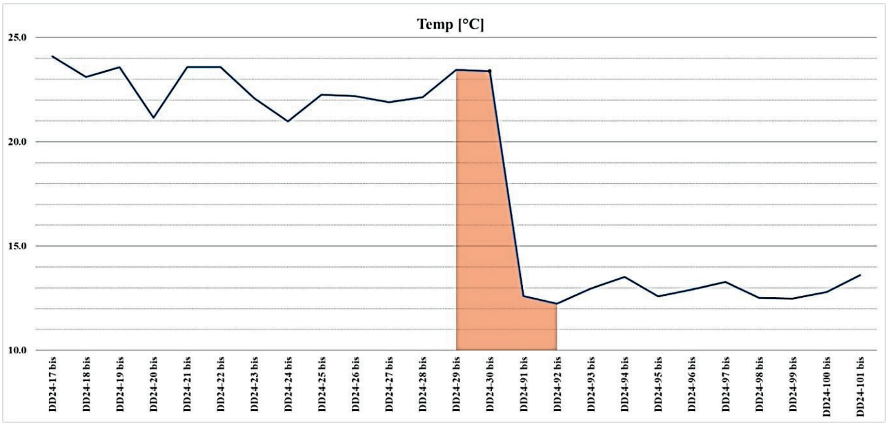
| Parameter | Min. | Max. | Mean ± SD |
|---|---|---|---|
| Temperature (°C) | 14.46 | 25.11 | 19.60±5.04 |
| pH | 8.05 | 8.33 | 8.16±0.07 |
| Turbidity (FNU) | 2.46 | 58.26 | 9.96±9.73 |
| Total Dissolved Solids (TDS mg/L) | 228.14 | 256.00 | 250.56±5.19 |
| Conductivity (µS/cm) | 300.82 | 385.10 | 345.38±34.89 |
| Dissolved Oxygen (ODO mg/L) | 7.14 | 9.93 | 8.54±0.94 |
| Oxygen Saturation (ODO % sat) | 85.73 | 97.41 | 92.34±2.85 |
| Oxidation-Reduction Potential (ORP mV) | 49.93 | 107.14 | 84.00±20.97 |
| Salinity (PSU) | 0.17 | 0.19 | 0.18±0.01 |
| Nitrate (NitraLED mg/L) | 0.11 | 18.36 | 5.78±4.73 |
| Chlorophyll (RFU) | 0.34 | 0.78 | 0.52±0.11 |
| Total Algal Content (TAL - PC RFU) | 0.10 | 1.37 | 0.64±0.41 |

Table 2. A synopsis of the physico-chemical parameters of water surface samples for Gorgova-Uzlina Complex

| Parameter | Min. | Max. | Mean ± SD |
|---|---|---|---|
| Temperature (°C) | 12.24 | 24.09 | 18.36±5.03 |
| pH | 7.77 | 8.98 | 8.20±0.30 |
| Turbidity (FNU) | 1.14 | 91.60 | 14.59±18.78 |
| Total Dissolved Solids (TDS mg/L) | 212.05 | 273.74 | 251.33±12.45 |
| Conductivity (µS/cm) | 292.84 | 399.04 | 336.99±35.20 |
| Dissolved Oxygen (ODO mg/L) | 4.67 | 14.13 | 9.14±1.92 |
| Oxygen Saturation (ODO % sat) | 53.47 | 166.61 | 96.82±22.07 |
| Oxidation-Reduction Potential (ORP mV) | -22.37 | 254.70 | 75.25±58.65 |
| Salinity (PSU) | 0.16 | 0.20 | 0.19±0.01 |
| Nitrate (NitraLED mg/L) | 0.10 | 10.46 | 4.64±3.35 |
| Chlorophyll (RFU) | 0.51 | 22.48 | 4.89±4.79 |
| Total Algal Content (TAL - PC RFU) | 0.44 | 12.47 | 2.78±3.17 |

*Water temperature (°C).* Water temperature generally follows the trend of autumn air temperatures (https://www.accuweather.com). Recorded values fell within the natural variability of the study areas. In the Gorgova-Uzlina Complex, temperatures ranged from 12.24 to 24.09 °C (average 18.36 °C), while in Ceatal Izmail and Sf. Gheorghe, they ranged from 14.46 to 25.11 °C (average 19.60 °C). The lowest temperature was recorded at station DD24-92 bis (Gorgova Lake), and the highest at station DD24-11 (Ceatal Izmail) (Figure 4a, b). These results reflect typical seasonal fluctuations, with temperature variation mainly influenced by air temperature dynamics during the sampling period.

*Water pH (pH units).* The values of the results obtained place the tested water from most of the investigated samples within the pH range of normal values (6.5-8.5 pH units), which is considered optimal for aquatic life. The range of variation of the values was relatively narrow (7.77-8.98, average = 8.20) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 8.05-8.33, average 8.16, so that the lowest value was found in station DD24-26 bis (Lake Isaccel), and the highest value was measured in station DD24-21 bis (Lake Isacova) (Figure 5 a, b). These pH values indicate that the water quality at the sampled sites is generally within a range favourable for the sustainability of aquatic ecosystems.

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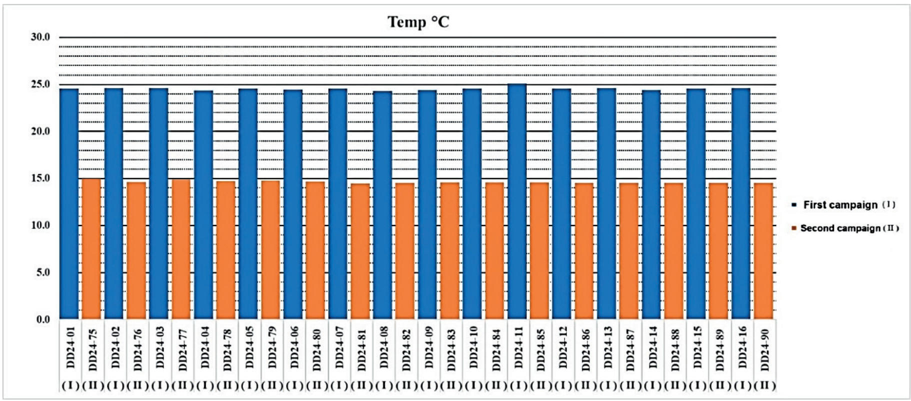


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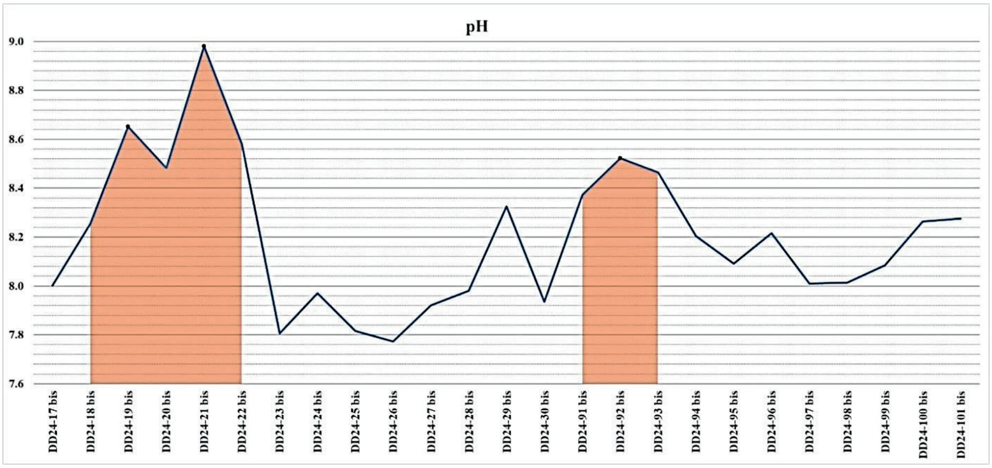
Figure 4 a) Evolution of the Temperature indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the Temperature indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

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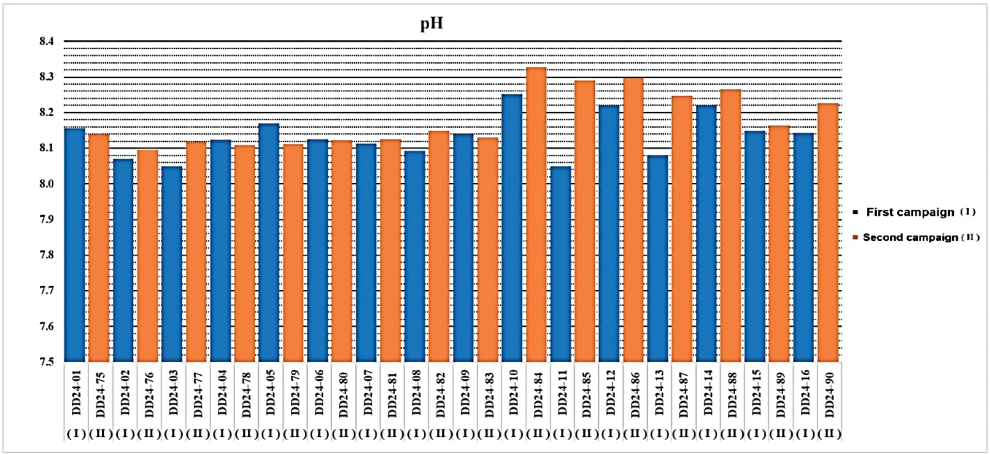
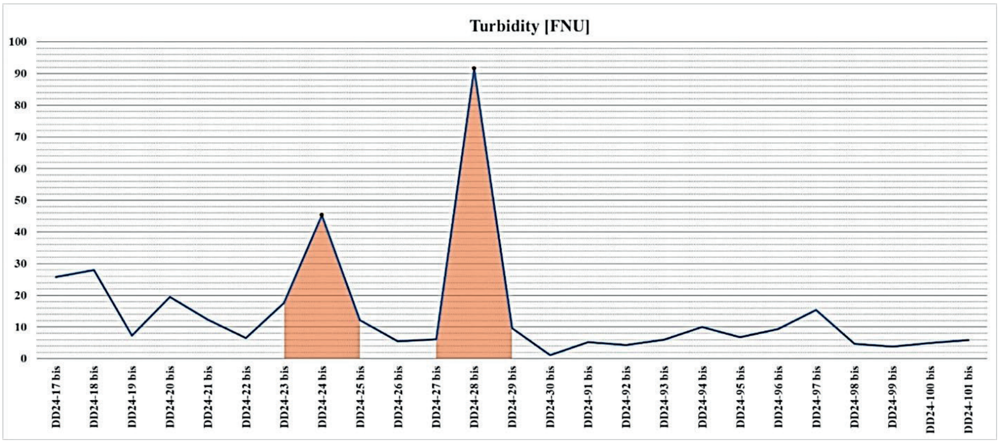



b

Figure 5 a) Evolution of the pH indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the pH indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

*Turbidity (NTU).* The turbidity values measured in the water samples taken from the study lakes show a series of variations that fall within the normal range of surface waters (1-1000 NTU) (Chapman, 1996). The range of values was relatively wide (1.14-91.60, average = 14.59) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 2.46-58.26, average 9.96, so that the lowest value was recorded in station DD24-30 bis, Clisciova Lake, and the highest value was measured in station DD24-28 bis, Isaccel Lake (Figure 6 a, b). several samples exhibited relatively high turbidity values compared to the limits stipulated in SR ISO 5667-5:2017, which sets 5 NTU as the allowed value and 10 NTU as the exceptionally allowed value~~), indicating a deterioration in water quality. In general, increased turbidity levels can be attributed to the Danube's fluvial input, which carries water and sediments loaded with dissolved or suspended organic/inorganic substances.

*The TDS concentration* (total dissolved organic and inorganic substances) places the tested water in a good condition (values corresponding to fresh waters = 0 – 1000 mg/L TDS), (Lehr, 1980; De Zuane, 1997). The range of variation of the values was relatively narrow (212.05-273.74; average = 251.33) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 228.14-256.00, average – 250.56, so that the lowest value was found in station DD24-19 bis, Lake Uzlina, and the highest value was measured in station DD24-25 bis, Lake Durnoliatca (Figure 7 a, b). These results indicate that the investigated lakes are in good condition in terms of the concentration of dissolved inorganic and organic substances and that the water is not excessively influenced by external sources of pollution.

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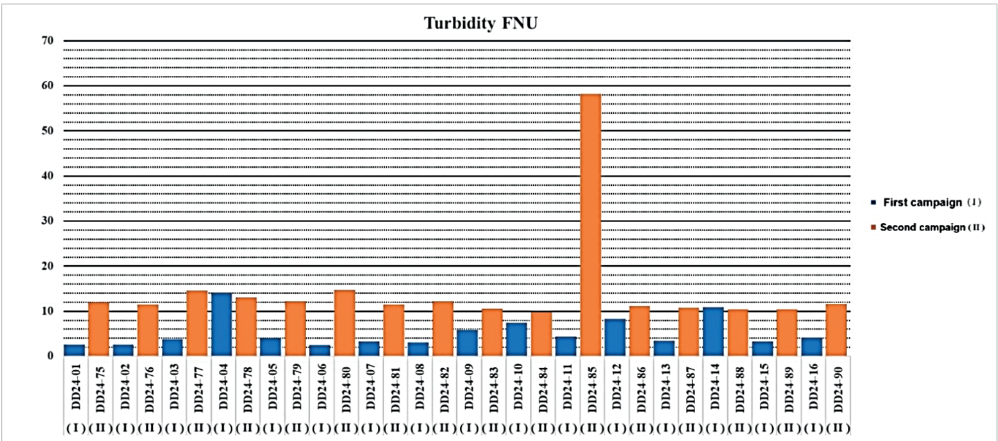


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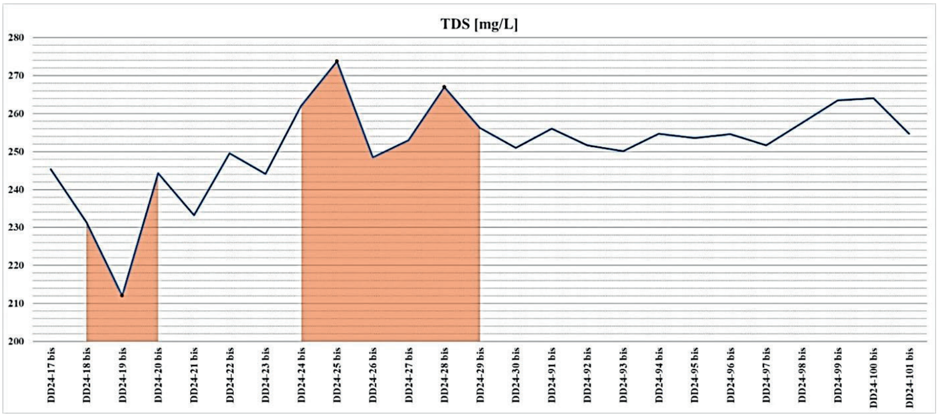
Figure 6 a) Evolution of the Turbidity FNU indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the Turbidity FNU indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

*The level of electrical conductivity* places the tested water from all investigated samples in the category of quality class I (500 µS/cm) (Order 161/2006). The range of variation of the values was relatively narrow (292.84-399.04, average = 336.99) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 300.82-385.10, average = 345.38, so that the lowest value was found in station DD24-92 bis, Lake Gorgova, and the highest value was measured in station DD24-25 bis, Lake Durnoliatca (Figure 8 a, b). These values are typical of freshwaters with low mineralization, which is characteristic of the studied lakes, indicating that the water chemistry is consistent with a good ecological status.

*The dissolved oxygen regime (mg/l)* ranged from quality class I - 9 mg/L to quality class IV - 4 mg/L (Order 161/2006). The dissolved oxygen concentrations (measured in all evaluated water samples) were also below the value of 5 mg/L. A minimum concentration of 5 mg/L dissolved oxygen is recommended to adequately support aquatic life (www.niwa.co.nz). The range of values includes a relatively wide gap (4.67-14.13, average = 9.14) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 7.14 and 9.93, average = 8.54, so that the lowest value was found in station DD24-23 bis, Durnoliatca Lake, and the highest value was measured in station DD24-21 bis, Isacova Lake (Figure 9 a, b). These variations suggest that oxygen levels in water are influenced by a variety of factors, including water temperature, biological activity and hydrodynamic conditions.

*The oxidation-reduction potential (ORP) (mV)* places the tested water in a good condition. The values obtained for the tested water samples fall within the ORP range of natural waters (with values in the range -500 to + 700 mV) (Chapman, 1996; Sigg, 2000). The range of variation was included in both the positive and negative spectrum (-22.37-254.70; average = 75.25) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 49.93-107.14, average 84.00, so that the lowest value was found in station DD24-17 bis, Uzlina Lake, and the highest value was measured in station DD24-27 bis, Isaccel Lake (Figure 10 a, b). These results suggest that water quality is generally good and that the investigated lakes maintain a healthy balance of redox reactions.

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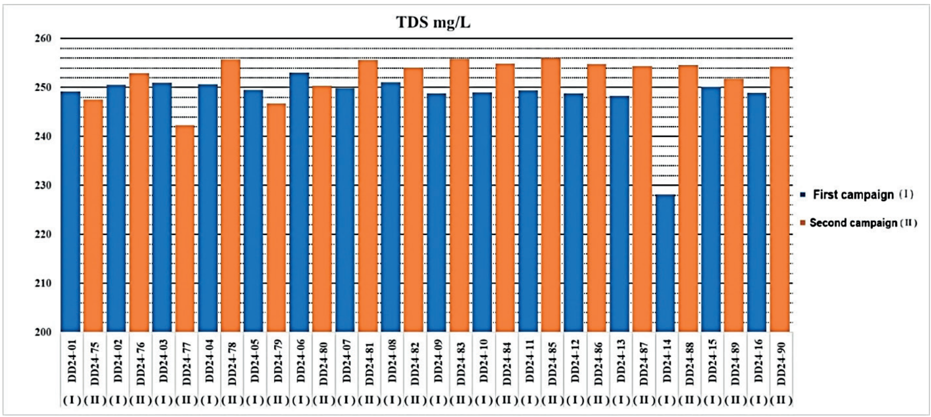
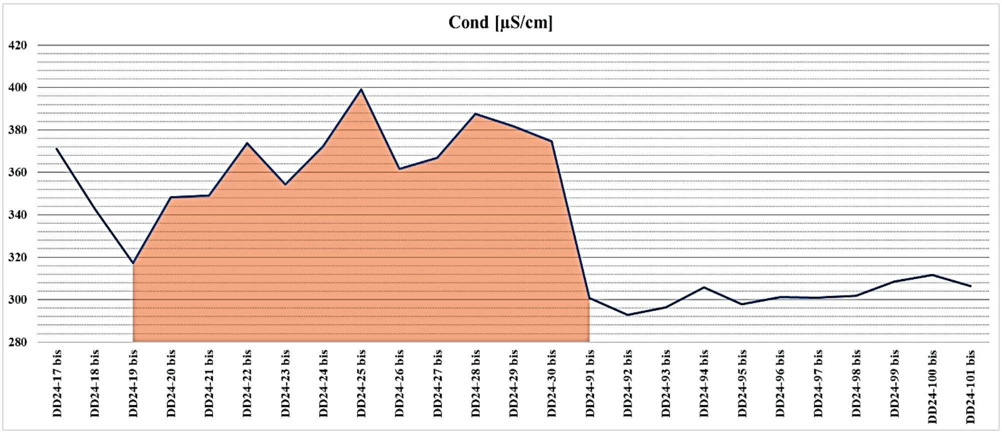



b

Figure 7 a) Evolution of the TDS mg/L indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the TDS mg/L indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

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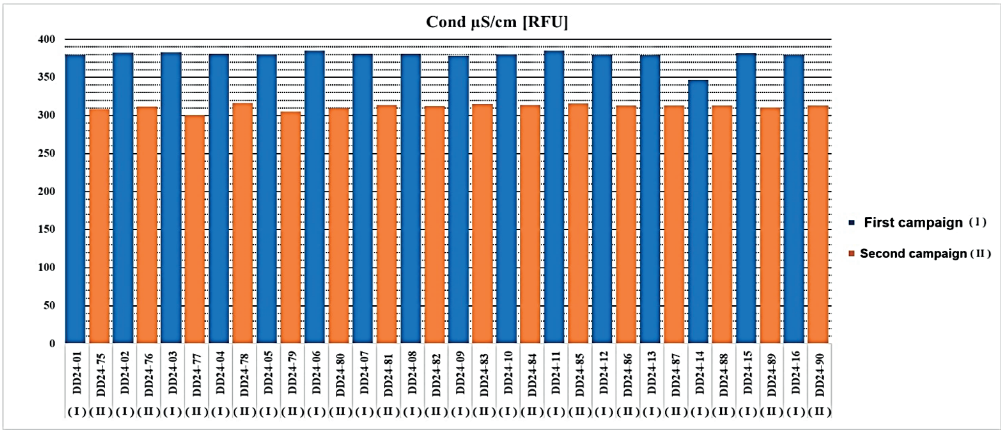


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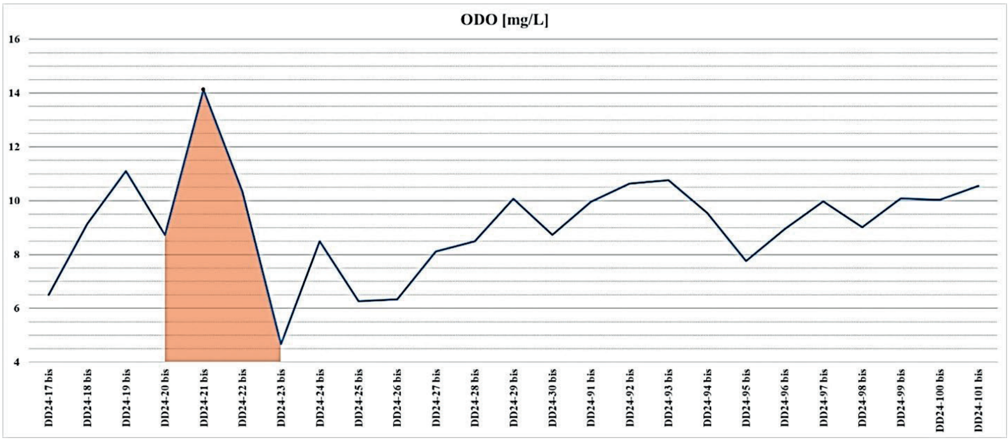
Figure 8 a) Evolution of the Cond µS/cm indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the Cond µS/cm indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

*Salinity level (‰)*. The investigated water samples showed salinity values ranging between 0.16-0.20‰ (average = 0.19) for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 0.17-0.19, average = 0.18. These values indicate fresh surface waters, with low salinity (salinity below 0.5‰) (Montagna et al., 2013) characteristic of the fluvial and lacustrine domain.

These low salinity values confirm that the lakes are characteristic of freshwater environments, typically found in fluvial and lacustrine settings, and are minimally influenced by marine waters.

*Distribution of nitrate concentrations.* Measurements made with the NitraLED sensor indicated significant variations in nitrate concentration (mg/L) at different sampling stations. The recorded values range from 0.10 mg/L to 10.46 mg/L, for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 0.11-18.36, average = 5.78, suggesting notable differences in the chemical composition of the water depending on location (Figure 11 a, b).

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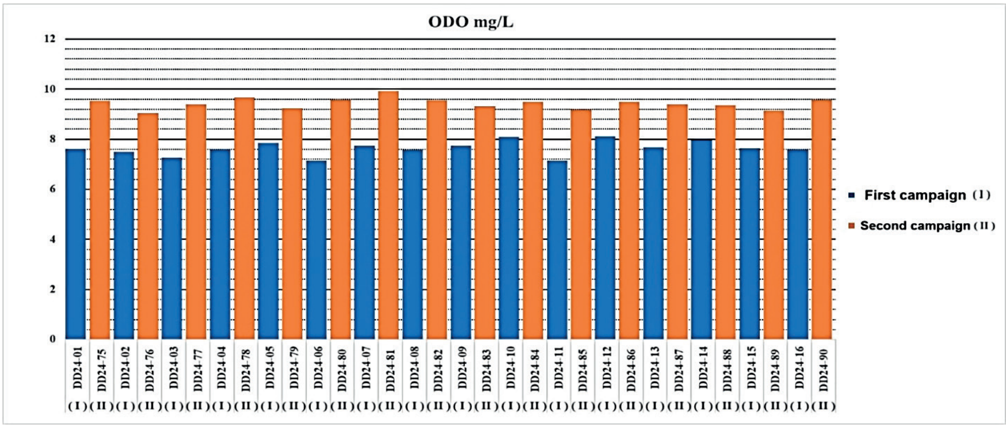


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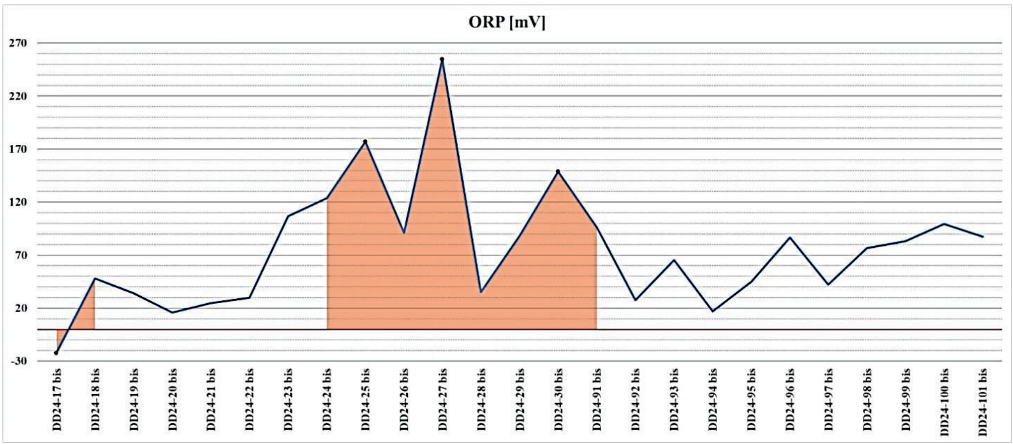
Figure 9 a) Evolution of the ODO mg/L indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the ODO mg/L indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

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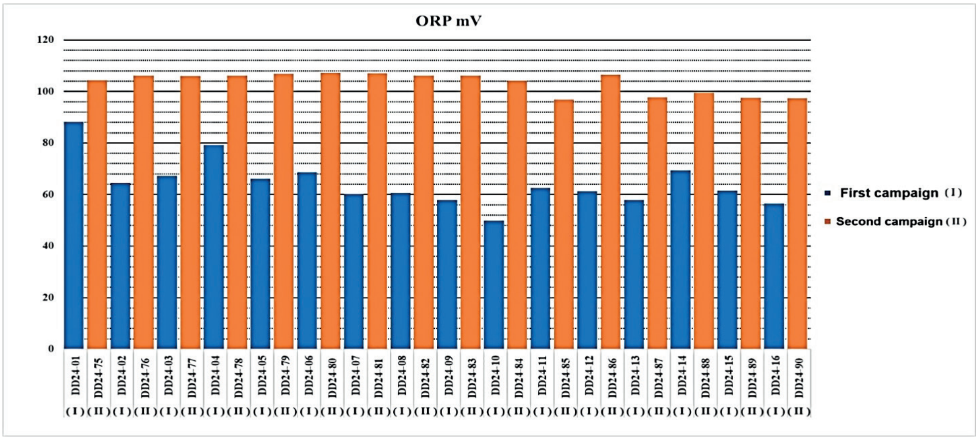


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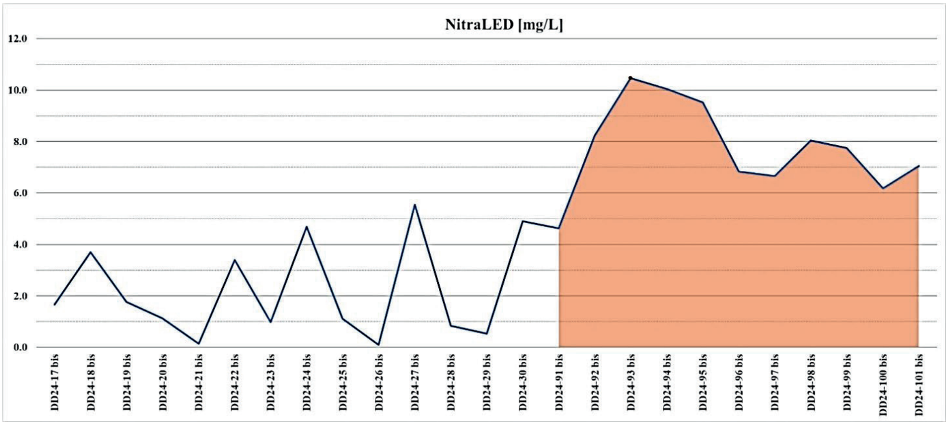
Figure 10 a) Evolution of the ORP mV indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the ORP mV indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

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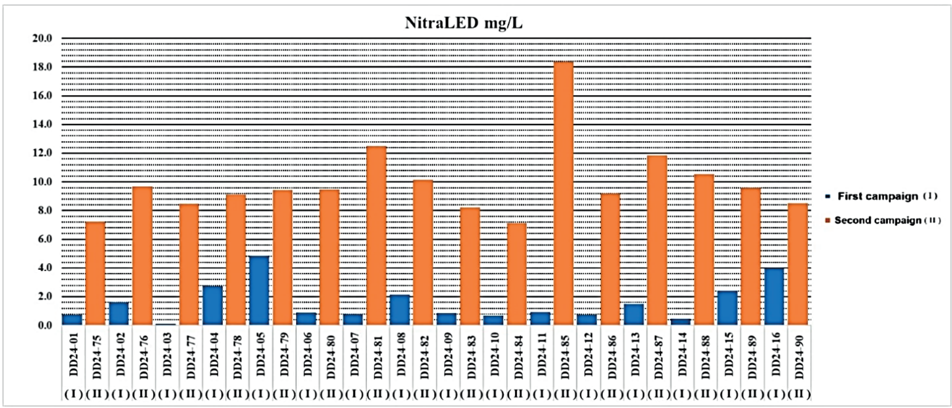


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Figure 11 a) Evolution of the NitraLED mg/L indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the NitraLED mg/L indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

**Grouping of stations by nitrate concentration**

- *Low concentrations (≤1 mg/L)*

Stations such as DD24-03 – Ceatal Izmail (0.1108 mg/L), DD24-26 bis – Isaccel lake (0.095 mg/L) and DD24-21 bis – Isacova lake (0.144 mg/L) indicate very low nitrate presence. These values may reflect areas with low anthropogenic impact or geochemical conditions that limit nitrate accumulation.

- *Moderate concentrations (1 – 5 mg/L)*

This range includes most of the stations in the first sets of measurements (e.g. DD24-02, DD24-04, DD24-15) – Ceatal Izmail and Ceatal Sf. Gheorghe in September, and the stations (e.g. DD24-17 bis, DD24-19 bis, DD24-22 bis) – Uzlina and Isacova Lakes.

Moderate values may indicate a natural influence or a limited source of pollution.

- *High concentrations (>5 mg/L)*

The highest values occur at stations DD24-75, DD24-76, DD24-81, DD24-85 – Ceatal Izmail in October, with a maximum concentration of 18.362 mg/L.

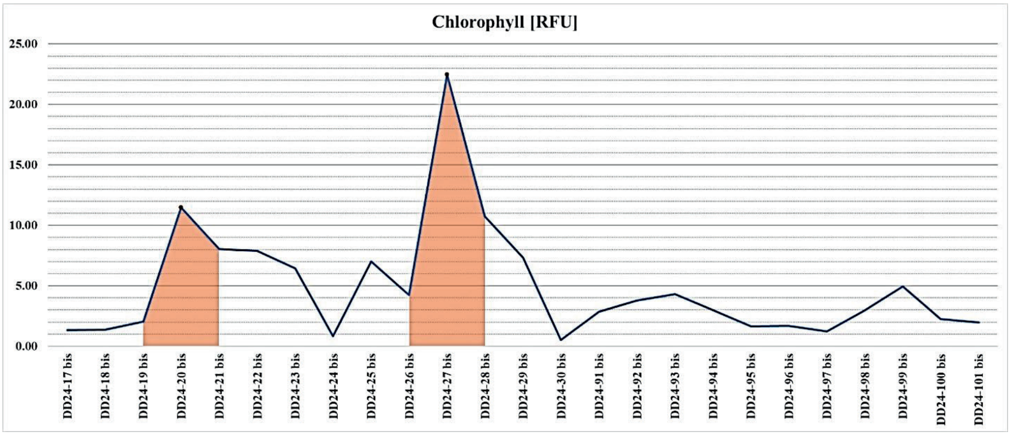
These concentrations are significantly higher and may indicate either a point source of contamination (e.g. anthropogenic activities, domestic effluents, agricultural inputs, industrial waste) or specific geological and hydrological factors, in the upstream urban section of the Danube River.

*The concentration of chlorophyll a RFU* concentration measured in the samples from the investigated lakes showed significant variability. Specifically, the values ranged broadly from 0.51 to 22.48 (mean = 4.89) in the Gorgova-Uzlina Complex and from 0.34 to 0.78 (mean = 0.52) in the Ceatal Izmail and Sf. Gheorghe areas. The lowest concentration was recorded at station DD24-81 (Ceatal Izmail), while the highest was observed at station DD24-27 bis (Isaccel Lake) (Figure 12 a, b).

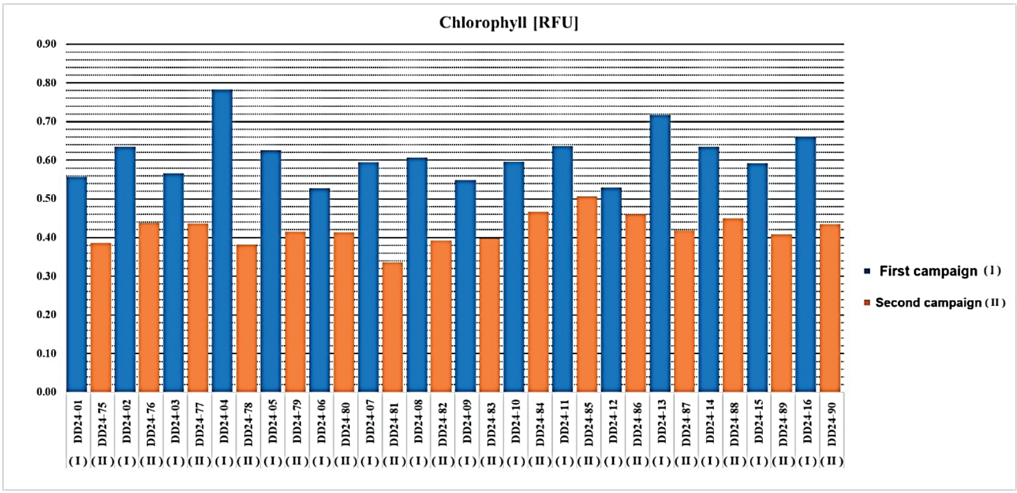
Several factors contribute to this variability:

- *Nutrient availability*: the main cause of variations in chlorophyll “a” concentration is the differences in nutrient availability (especially nitrogen and phosphorus) between lakes. High nutrient levels can stimulate algal growth, leading to increased chlorophyll concentrations.
- *Hydrological conditions*: Lakes differ in water renewal rates, connectivity to major channels, and water residence time. Lakes with slower water exchange rates or limited flushing often accumulate nutrients, promoting higher algal productivity.
- *Biological activity*: Differences in algal community composition and the presence or absence of macrophytes or other aquatic vegetation can significantly influence chlorophyll levels. Lakes with abundant aquatic vegetation may have lower chlorophyll concentrations due to competition for nutrients.
- *Anthropogenic influence*: Human activities, such as agricultural runoff, wastewater discharge, or fish farming operations, can lead to increased nutrient inputs, stimulating algal growth and chlorophyll concentration.
- *Physical factors*: Light availability, temperature variations and mixing conditions in lakes can also affect algal growth rates and therefore chlorophyll concentrations.

Most samples showed chlorophyll values below the threshold of 25 μg/l established for water quality class I (very good status) according to Order 161/2006, suggesting that the lakes generally have a good ecological status in terms of primary productivity. However, the wide range of chlorophyll values clearly indicates variability driven by the interaction between nutrient dynamics, hydrological conditions, biological communities, anthropogenic pressures and physical environmental factors.



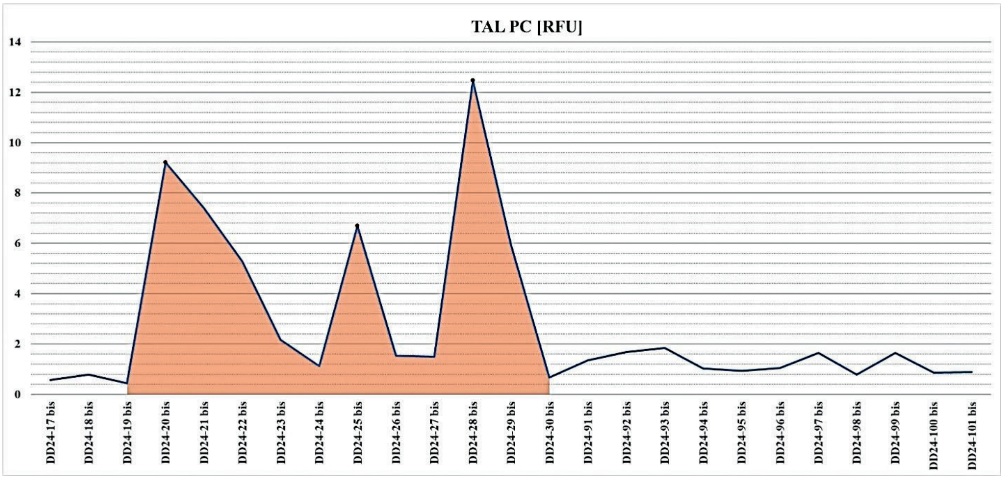

a




b

Figure 12 a) Evolution of the chlorophyll a RFU indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the chlorophyll a RFU indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

*Total Algal Content (TAL - PC RFU).* The TAL PC values show significant variations between stations, ranging from a minimum of 0.44 µg/L to a maximum of 12.47 µg/L, average = 2.78, for Gorgova-Uzlina Complex and for Ceatal Izmail and Sf. Gheorghe, the values varied between 0.10-1.37, average = 0.64 (Figure 13, a b). The lowest concentration values (below 0.5 µg/L) occur at stations DD24-78, DD24-79 and DD24-80, indicating reduced contamination or better water quality conditions at these points. In contrast, the highest concentrations (above 1.5 µg/L) are observed at stations DD24-92 bis, DD24-93 bis, DD24-97 bis and DD24-99 bis, suggesting possible local sources of pollution or increased accumulation of the analysed compounds. Most values are around the range of 0.8-1.2 µg/L, indicating a moderate concentration, possibly reflecting a relatively balanced state of the waters at most of the investigated points. The distribution of the data may suggest differences in the intensity of anthropogenic or natural factors influencing each sampling point, reflecting specific local impacts.

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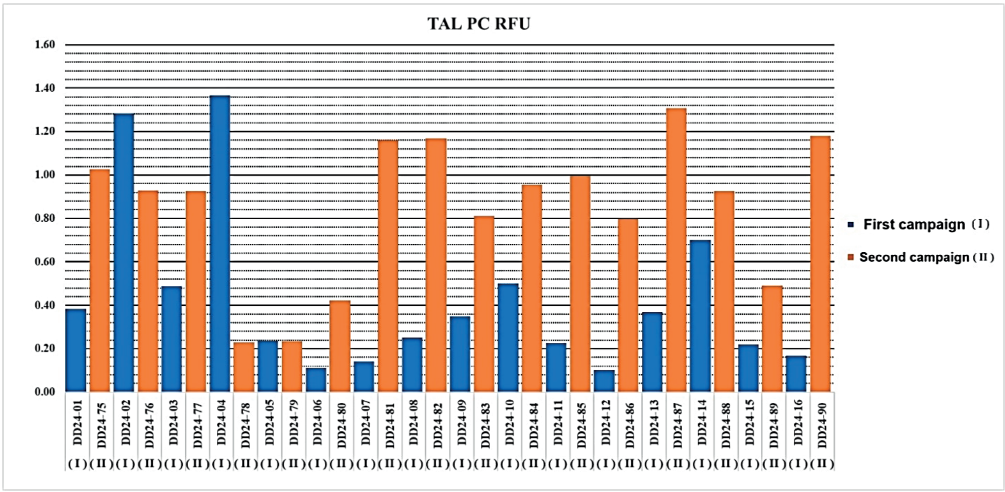


b

Figure 13 a) Evolution of the Total Algal Content (TAL - PC RFU) indicator in the investigated surface water samples for Gorgova-Uzlina Complex; b) Evolution of the Total Algal Content (TAL - PC RFU) indicator in the investigated surface water samples for Izmail and Sf. Gheorghe Confluences

Based on Pearson correlation for all the samples, a strong positive correlation was found between (Table 3, Figure 14):

**Strong positive correlations**:

- ODO % sat and ODO mg/L (0.803): As expected, the percentage of dissolved oxygen saturation and its concentration measured in mg/L are strongly correlated. This is because both measure oxygen, but in different units, influenced by temperature and pressure.
- Salinity and TDS (0.937): Total dissolved solids (TDS) concentration is closely related to salinity, as dissolved salts contribute significantly to TDS.
- Conductivity and temperature (0.936): As temperature increases, the conductivity of water increases significantly, as ions in the water become more mobile.

**Strong negative correlations**:

- Temperature and TAL PC ug/L (-0.892): As temperature increases, the concentration of algal pigments decreases significantly, suggesting a decrease in phytoplankton biomass under warmer conditions.

- Temperature and NitraLED mg/L (-0.838): Higher temperatures are associated with lower nitrate levels, likely due to increased biological consumption in the ecosystem.
- Temperature and ODO mg/L (-0.498): While there is a negative relationship between temperature and dissolved oxygen, the correlation is moderate. In general, warmer water holds less oxygen.

**Moderate correlations**:

- pH and ODO % sat (0.811): higher pH is correlated with higher oxygen saturation, likely due to photosynthetic activity.
- pH and ORP (-0.420): There are a moderately negative relationship between pH and redox potential (ORP), suggesting that at higher pH, the environment becomes more reductive.
- TAL PC ug/L vs. NitraLED mg/L (0.748) → The number of algal pigments is correlated with the concentration of nitrates, suggesting that nitrates are an important source of nutrients for phytoplankton.

**Weak correlations**:

- Chlorophyll RFU and turbidity (0.191): The relationship between chlorophyll levels measured by fluorescence and turbidity is weak. Therefore, algae growth does not fully explain water turbidity.
- Chlorophyll ug/L and temperature (-0.676): Chlorophyll measured as actual concentration is negatively influenced by temperature, but to a moderate to strong extent.

Table 3. Proximity matrix (Pearson correlation coef.)

| | Chlorophyll RFU | Chlorophyll ug/L | Cond µS/cm | ODO % sat | ODO mg/L | ORP mV | Sal psu | TAL PC RFU | TAL PC ug/L | TDS mg/L | Turbidity FNU | pH | Temp °C | NitraLED mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chlorophyll RFU** | **1.000** | 0.040 | 0.172 | 0.170 | 0.060 | 0.244 | 0.159 | 0.637 | -0.162 | 0.091 | 0.191 | 0.052 | 0.129 | -0.217 |
| **Chlorophyll ug/L** | 0.040 | **1.000** | -0.622 | -0.027 | 0.399 | -0.099 | 0.433 | -0.083 | 0.754 | 0.284 | -0.164 | 0.181 | -0.676 | 0.426 |
| **Cond µS/cm** | 0.172 | -0.622 | **1.000** | -0.036 | -0.589 | -0.072 | -0.234 | 0.203 | -0.843 | -0.004 | 0.043 | -0.273 | 0.936 | -0.787 |
| **ODO % sat** | 0.170 | -0.027 | -0.036 | **1.000** | 0.803 | -0.249 | -0.366 | 0.314 | -0.054 | -0.410 | -0.001 | 0.811 | 0.114 | -0.091 |
| **ODO mg/L** | 0.060 | 0.399 | -0.589 | 0.803 | **1.000** | -0.101 | 0.011 | 0.183 | 0.499 | -0.141 | 0.004 | 0.765 | -0.498 | 0.419 |
| **ORP mV** | 0.244 | -0.099 | -0.072 | -0.249 | -0.101 | **1.000** | 0.421 | -0.147 | 0.064 | 0.369 | -0.085 | -0.420 | -0.200 | 0.276 |
| **Sal psu** | 0.159 | 0.433 | -0.234 | -0.366 | 0.011 | 0.421 | **1.000** | 0.192 | 0.468 | 0.937 | 0.208 | -0.328 | -0.547 | 0.435 |
| **TAL PC RFU** | 0.637 | -0.083 | 0.203 | 0.314 | 0.183 | -0.147 | 0.192 | **1.000** | -0.148 | 0.179 | 0.525 | 0.214 | 0.127 | -0.262 |
| **TAL PC ug/L** | -0.162 | 0.754 | -0.843 | -0.054 | 0.499 | 0.064 | 0.468 | -0.148 | **1.000** | 0.297 | -0.057 | 0.182 | -0.892 | 0.748 |
| **TDS mg/L** | 0.091 | 0.284 | -0.004 | -0.410 | -0.141 | 0.369 | 0.937 | 0.179 | 0.297 | **1.000** | 0.182 | -0.426 | -0.354 | 0.283 |
| **Turbidity FNU** | 0.191 | -0.164 | 0.043 | -0.001 | 0.004 | -0.085 | 0.208 | 0.525 | -0.057 | 0.182 | **1.000** | -0.099 | -0.024 | 0.123 |
| **pH** | 0.052 | 0.181 | -0.273 | 0.811 | 0.765 | -0.420 | -0.328 | 0.214 | 0.182 | -0.426 | -0.099 | **1.000** | -0.103 | 0.073 |
| **Temp °C** | 0.129 | -0.676 | 0.936 | 0.114 | -0.498 | -0.200 | -0.547 | 0.127 | -0.892 | -0.354 | -0.024 | -0.103 | **1.000** | -0.838 |
| **NitraLED mg/L** | -0.217 | 0.426 | -0.787 | -0.091 | 0.419 | 0.276 | 0.435 | -0.262 | 0.748 | 0.283 | 0.123 | 0.073 | -0.838 | **1.000** |

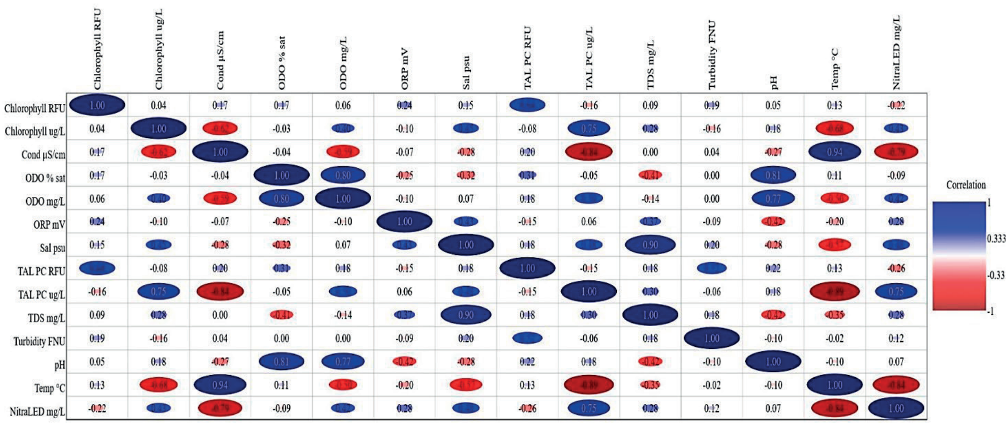


Figure 14. Pearson correlation

The physico-chemical parameters measured in this study varied within ranges compatible with natural seasonal fluctuations and environmental standards. Water temperature closely followed air temperature trends, reflecting typical autumn conditions. pH values consistently indicated optimal conditions for aquatic life, demonstrating stability in the ecosystem. Turbidity levels showed a wide range, with some stations showing high values, probably influenced by sediment inputs from the Danube River. Electrical conductivity and total dissolved solids (TDS) values demonstrated typical freshwater conditions with low mineralization, indicating minimal impacts of external pollution. Similarly, low salinity values confirmed the predominantly freshwater nature of the lakes.

Dissolved oxygen levels showed significant variability, with some sites recording concentrations below the recommended minimum of 5 mg/L, potentially influenced by biological activity and hydrodynamic conditions. Oxidation-reduction potential (ORP) values fell within natural limits, indicating healthy redox conditions in the water bodies. Nitrate concentrations varied significantly, highlighting areas with potential anthropogenic impact. Chlorophyll “a” concentration generally indicated very good ecological conditions, although some sites displayed higher values, suggesting localized variations in nutrient availability and primary productivity. In addition, the total algal content (TAL - PC RFU) reflects variations in primary productivity and algal biomass between sampling points, highlighting potential eutrophication patterns. The observed variability in TAL PC values could thus be related to differences in nutrient availability, water circulation or local anthropogenic inputs influencing algal growth.

The results obtained in this study on the physicochemical parameters of the Danube Delta waters closely align with the findings of previous research conducted in the same region and in similar environments. Studies focused on areas such as the Gorgova-Uzlina Depression, the Somova-Parches area and the Matita-Merhei Complex have similarly reported good overall ecosystem conditions (Botnariuc, 1985). Furthermore, the measured values are consistent with those documented in other recent water quality assessments for the Sfântu Gheorghe and Chilia branches (Sener et al., 2016; Oz et al., 2019; Teodorof et al., 2021) and the predeltaic area near Galați (Iticescu et al., 2014). Collectively, these studies suggest a medium-term stability of the hydrochemical characteristics in the Danube Delta region (Karabulut et al., 2014).

Pearson correlation analysis revealed strong relationships between parameters such as dissolved oxygen and oxygen saturation, salinity and TDS, as well as conductivity and temperature. These correlations indicate interdependencies between physicochemical factors and underline the importance of integrated monitoring approaches for managing the ecological health of the Danube Delta.

## CONCLUSIONS

To determine the water quality status of the studied areas of the Izmail and Sf. Gheorghe Rivers and the Danube Delta, several physicochemical parameters were evaluated, including temperature, pH, turbidity, total dissolved solids (TDS), conductivity, dissolved oxygen, oxygen saturation, oxidation-reduction potential (ORP), salinity, nitrate concentration, chlorophyll and total algae content (RFU-PC). The measurements and interpretations followed the established reference standards and methods.

• *Water quality in the investigated ecosystems of the confluence areas and lakes of the Gorgova Uzlina Lake Complex*.

According to the analysed parameters, most of the water samples from the studied lakes and canals fell predominantly into quality classes I and II according to Order 161/2006, indicating a generally good ecological status. However, localized variations were identified, reflecting specific environmental conditions or pressures.

• *Ecological vulnerabilities and anthropogenic pressures*

Ecosystems remain vulnerable to fluvial inputs of organic and inorganic substances, influencing turbidity and dissolved substance concentrations. Elevated turbidity values recorded in certain locations, such as Lake Isaccel, highlight potential negative impacts on aquatic organisms and overall water quality, requiring continuous monitoring.

• *Physico-chemical water parameters*

Temperature (°C): the values recorded were characteristic of the autumn season, showing minimal variability and remaining within natural limits.

pH (pH units): most samples indicated values within the normal range (6.5–8.5), suggesting a chemically stable aquatic environment.

Turbidity (FNU): localised increased turbidity was observed, indicating variations due to sediment influx or anthropogenic impact, which may negatively affect aquatic life.

Total Dissolved Solids (TDS) (mg/L): values were consistent with freshwater systems, reflecting limited dissolved salt content.

Conductivity (µS/cm): all measurements are aligned with quality class I, confirming the minimal presence of dissolved salts and indicating low contamination.

Dissolved Oxygen (ODO mg/L) and Oxygen Saturation (ODO%): although generally reflecting good ecological status, certain locations (e.g. Durnoliatca Lake) showed lower dissolved oxygen values (below 5 mg/L), posing risks to aquatic biota.

Oxidation-Reduction Potential (ORP, mV): ORP values indicate favourable oxidative conditions in most locations, leading to a balanced ecological environment.

Salinity (PSU): the recorded values affirmed the freshwater nature of the studied aquatic environments, with no significant saline influence.

Nitrate (NitraLED mg/L): concentrations were within acceptable limits, with no significant indication of nutrient pollution in the studied areas.

Chlorophyll (RFU): Chlorophyll values remained generally low, suggesting minimal risks of eutrophication and reduction of algal biomass.

Total Algal Content (TAL-PC RFU): significant variations were identified between stations, reflecting differences in nutrient availability or localized anthropogenic influences affecting algal biomass.

• *Risk factors and recommendations*

Sediment and organic matter inputs from the Danube significantly influence water quality. Continuous monitoring is essential to detect and mitigate potential deterioration, especially in areas with high turbidity and low dissolved oxygen levels.

Future monitoring efforts should correlate physicochemical data with meteorological and hydrological conditions of the Danube – Danube Delta lakes, improving the understanding of seasonal and anthropogenic impacts on these sensitive ecosystems.

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