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ASSESSMENT OF SURFACE WATER QUALITY ACROSS SELECTED DANUBE RIVER SECTORS BASED ON PHYSICO-CHEMICAL PARAMETERS AND HYDROCARBON LEVELS

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Abstract

This study evaluated the surface water quality of selected Danube River sectors (km 549-990) in the RO13 Cazane-Călărași area using direct field measurements. A multiparameter EXO 2 probe (YSI, USA) was used to analyze key physico-chemical parameters, while hydrocarbon concentrations (Oil in Water and HC micro-g/L) were assessed using PAH probes. Results indicate that most water quality parameters remain within environmental standards, classifying the waters as either "Very Good" or "Good." Temperature (15.03-24.40°C) and pH (7.92-8.36) remained stable, while dissolved oxygen levels (7.01-9.43 mg/L) and chlorophyll concentrations (0.27–1.49 RFU) suggested low risk of eutrophication. Conductivity (262.53-411.56 µS/cm), TDS (207.56-280.80 mg/L), and salinity (0.15-0.21 psu) confirmed freshwater conditions. Turbidity values (2.44-28.75 FNU) and oxidation-reduction potential (-26.59 to 238.79 mV) indicated relatively stable conditions. Hydrocarbon levels (0.03-1.46 mg/L) were within acceptable environmental limits, though localized variations suggested potential pollution sources. These findings emphasize the need for long-term monitoring and transboundary collaboration to address localized pollution concerns and ensure sustainable water management in the Danube Basin.

***Key words**: Danube River, surface water quality, hydrocarbon pollution, ecosystem monitoring, environmental assessment.*

INTRODUCTION

The Danube, the second longest river in Europe, crosses ten countries and plays a key role in the economy, biodiversity and hydrological dynamics of the region (Banu, 1967; Panin, 2003). The lower Danube, between Drobeta-Turnu Severin and the Black Sea, is characterized by a complex hydrographic network, fed by tributaries such as the Siret, Olt, Prut and Jiu. In this area, hydromorphological diversity determines significant variations in the flow regime, sediment transport and distribution of aquatic habitats (Călinescu & Iana, 1967; Bușniță et al., 1970; Cioboiu & Brezeanu, 2017; Nike et al., 2022). Assessing water quality in this sector is essential for monitoring the impact of anthropogenic pressures and climate change on the river ecosystem (Calmuc et al., 2020; Radu et al., 2022). The main threats to water quality include pollution with nutrients, hazardous substances, hydromorphological changes and organic pollution (Gasparotti, 2014). These problems are aggravated by industrial, agricultural and urban activities in the Danube basin, which influence the physico-chemical parameters of the water and, implicitly, the ecological status of the river (Rico et al., 2016).
This research aims to answer the question: How do natural and anthropogenic factors influence water quality in the Lower Danube? To address this, the study assesses spatial and temporal variations in key physicochemical water parameters, including temperature, pH, dissolved oxygen (DO), chlorophyll, turbidity, salinity, total dissolved solids (TDS), oxidation-reduction potential (ORP), and hydrocarbon contamination.
By identifying potential pollution sources and assessing deviations from reference standards, this research provides insights into both natural variability and human-induced impacts on Danube water quality. The findings contribute to ongoing monitoring efforts and serve as a reference for future water management and conservation strategies in the region.

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Relevance and impact of the study

By analyzing water quality and hydromorphological pressures in detail, this research contributes to sustainable management strategies and the implementation of the Water Framework Directive (WFD). The results will support the development of effective measures to reduce pollution, protect aquatic biodiversity and improve navigation, providing a solid scientific basis for conservation policies and sustainable use of Danube River resources.

According to Annex XI of the Water Framework Directive (WFD), the Danube is classified within the Pontic Ecoregion. Based on the hydromorphological and physico-chemical characteristics outlined in the River Basin Management Plans, 19 distinct natural river types have been identified for the Danube and its delta. These classifications play a crucial role in assessing water quality, monitoring ecosystem health, and guiding conservation strategies.

MATERIALS AND METHODS

Study sectors

The selection and delimitation of key monitoring sectors in the Lower Danube were based on hydromorphological characteristics and anthropogenic pressures.

The primary investigated sectors included Calnovat (km 604-616; D2_24_01 - D2_24_39), Corabia (km 626-631), Bechet (km 674-678; D2_24_40 - D2_24_54), Pisculet Desa (km 760-631; D2_24_26_; D2_24_72), and Bogdan Seclan (km 781-786; D2_24_73 - D2_24_90). These locations were chosen based on their hydromorphological diversity and potential exposure to anthropogenic influences.

In addition to these core sectors, supplementary sampling points were distributed in key areas to capture a comprehensive picture of spatial variations in water quality. These included sites downstream (km 594) and upstream (km 599) of Zimnicea, upstream of the Iskar River (km 638), as well as both downstream (km 689) and upstream (km 696) of the Jiu River. Further sampling was carried out upstream of Kozloduy (km 705 and 407), at the Lom River, upstream of Vidin/downstream of Calafat (km 794), upstream of Calafat (km 798) and near the Timok River, both downstream (km 844) and upstream (km 847). Additional sites were surveyed around the Iron Gates II Dam (km 860-878), a critical hydropower infrastructure that influences the hydrodynamics of the Danube.

Further upstream, monitoring was conducted at strategic locations, including downstream (km 882) and upstream (km 885) of Brza Palanka, downstream (km 925) and upstream (km 934) of Drobeta-Turnu Severin, and several locations in the Orșova region. These included downstream (km 951), Orșova Bay (km 954), and upstream of Orșova (km 954). Additional sites were examined in Eșelnița (km 963), downstream (km 968) and upstream (km 971) of Dubova, as well as downstream (km 986) and upstream (km 990) of the Poreka River.

These study sites are part of the RO13 Danube – Cazane - Călărași sector, ensuring a comprehensive assessment of hydromorphological conditions, pollution sources and ecosystem health in the lower Danube (Figure 1).

Methodology for analyzing physico-chemical parameters of water

The assessment of surface water quality in selected Danube sectors was conducted through in situ measurements of key physico-chemical parameters across 201 monitoring stations.

Field analyses were performed using the EXO 2 multiparameter probe (YSI - USA) (Figure 2), which utilizes physical, optical, and electrochemical detection methods to collect water quality data through a variety of sensors.

Measured parameters: 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.

Additionally, Polycyclic Aromatic Hydrocarbon (PAH) levels were monitored using PAH probes (microFlu oil sensors) for real-time hydrocarbon detection in water (Figure 2).

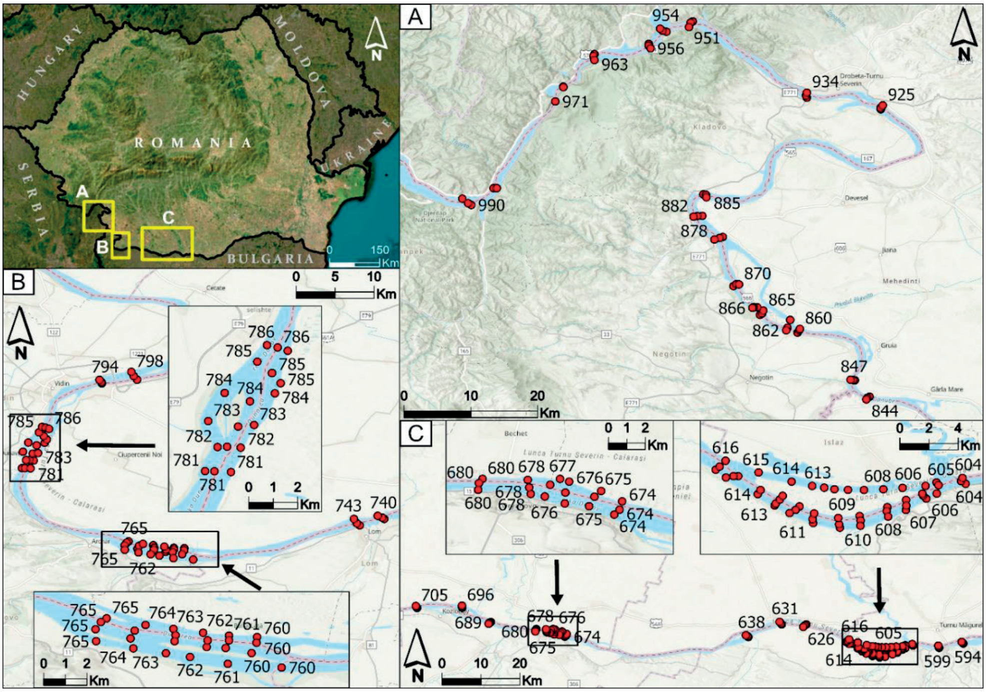

Figure 1. Sampling stations on the Danube River

The water quality assessment was carried out mainly based on the classification provided for in Order 161/2006, which defines five quality classes:

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

For comprehensive analysis, both national and international standards regulating water quality were taken into account. The EU Water Framework Directive (WFD, 2000/60/EC) requires qualitative and quantitative management of water resources, with the objective of maintaining healthy aquatic ecosystems and achieving "good status" of water quality. In this regard, the assessment of surface water quality was carried out in accordance with the Romanian National Environmental Standards, in particular Regulation no. 161/2006 (on the approval of reference objectives for the classification of surface water quality, Official Gazette of Romania, Part I, no. 511 bis). This regulation establishes the criteria for the classification of surface waters and the assessment of ecological status, using environmental parameters such as total dissolved solids (TDS) and turbidity (ISO 5667-5:2017).

The physicochemical determinations were carried out in accordance with applicable international standards, including SR ISO 5667/2007 (General Guide for the Establishment of Sampling Programs and Techniques), SR EN ISO 10523:2012 for the determination of pH and SR ISO 5814:1984 for the measurement of dissolved oxygen (DO). The data obtained for the physicochemical parameters of water at the sampling points are presented in Table 1, highlighting the minimum, maximum and average values (± standard deviation) for each parameter.

Methodology for hydrodynamic measurements (velocities, currents, and water discharges)

Hydrodynamic measurements, including current velocity, flow rate and direction, are essential for understanding the distribution and transport of pollutants in the aquatic environment. They influence both chemical dispersion and oxygenation and sedimentation processes,

having a direct impact on water quality (Kern et al., 2014; Teodorof et al., 2015; Iticescu et al., 2016; Catianis et al., 2024).
To determine the hydrodynamic parameters, a high-precision system based on the Doppler effect was used - Acoustic Doppler Current Profiler (ADCP), model River Ray 600 kHz, produced by Teledyne RD Instruments. The measurements were carried out exclusively in the sectors Calnovat, Corabia, Bechet, Pisculet Desa and Bogdan Seclan (Figure 2).

Statistical analysis
All statistical analyses were performed using xlSTAT 7.5.2 software (Addinsoft, 2020) and Past 4 (https://past.en.lo4d.com/download). Correlation between parameters were analysed using the Pearson correlation.

Figure 2. Multiparameter probe, model EX02 and the PAH probes, microFlu from Aquams and ADCP River Ray 600 kHz

RESULTS AND DISCUSSIONS

Water is a central element in the integration of various environmental concerns and strategies, playing an essential role in multiple human activities, such as agriculture, economy, transport, energy, industry and environmental protection (Podlasek et al., 2024). It is a determining factor in development, being indispensable both for maintaining the balance of aquatic ecosystems and for human health and well-being, ensuring fundamental needs such as food, hygiene, comfort and health (Gasparotti, 2014). Water quality is significantly influenced by industrial and agricultural activities, energy production and domestic activities (Banaduc et al., 2016). In the context of climate change, a resilient and integrated approach to water resources management is required (Poff et al., 2002; Capon et al., 2013).

Water quality parameters analysis
The values of the physicochemical parameters generally varied within the limits established by environmental standards (Table 1).
Rapid and persistent increases in global temperatures are expected in the coming decades (Diop et al., 2018). Global warming does not only affect the atmosphere, but also significantly influences aquatic environments (Hannesson, 2007). This phenomenon has led to an increase in the global average temperature of between 1.8 and 4.0°C, changes in climatic and hydrodynamic patterns, and rising sea levels (Madeira et al., 2016; Simionov et al. 2020).
Water temperature is closely linked to seasonal air temperature variations, particularly in autumn (https://www.accuweather.com). The recorded values ranged from 15.03°C to 24.40°C (mean 18.55°C), aligning with natural seasonal fluctuations. The lowest temperature was measured at km 968 (left bank), while the highest was recorded at km 631 (center). These variations can influence biological activity, affecting metabolic rates of aquatic organisms and oxygen solubility (Figure 3).
Water pH (pH units). The measured pH values ranged from 7.92 to 8.36 (mean 8.10), staying within the expected range for freshwater systems (6.5-8.5). These stable conditions indicate no significant acidification or alkalization events. The lowest pH was observed

at km 860 center, while the highest was recorded at km 605 right bank. The slight alkalinity corresponds to the buffering capacity of the Danube, primarily influenced by the carbonate-bicarbonate balance (Figure 4).

Turbidity (NTU). The turbidity values measured in the investigated water samples exhibited variations within the normal range for surface waters (1-1000 NTU) (Chapman, 1996). Turbidity ranged from 2.44 to 28.75 FNU, with a mean of 11.02 FNU, the highest value recorded at km 762 right bank, and the lowest at km 611 bis left bank. Although turbidity fluctuated widely, several values exceeded the 10 NTU limit specified in ISO 5667-5:2017. Increased turbidity at km 762 right bank was likely caused by sediment resuspension or an increased particle load from the upstream fluvial inlet. In contrast, the lowest turbidity recorded at km 611 Bis left bank may be attributed to reduced sediment influx or localized settling processes that contributed to water clarification. Overall, turbidity variations were primarily influenced by the Danube's fluvial input, which transports water and sediments loaded with dissolved and suspended organic/inorganic substances (Figure 5).

The *TDS concentration (*representing total dissolved organic and inorganic substances) indicates that the tested water is in good condition, with values consistent with freshwater standards (0-1000 mg/L TDS) (Lehr, 1980; De Zuane, 1997). The TDS concentration ranged from 207.56 to 280.80 mg/L, with a mean of 249.47 mg/L, the lowest value recorded at km 762 Bis right bank, and the highest at km 740 (right bank). These values suggest limited influence of dissolved salts or pollutants from upstream sources (Figure 6).

The *electrical conductivity* values ranged from 262.53 to 411.56 µS/cm, with a mean of 337.56 µS/cm (Figure 7). Electrical conductivity and TDS values confirm the freshwater characteristics of the investigated sectors, with no significant deviations that would indicate excessive mineralization or contamination.

Table 1. Synopsis of physico-chemical parameters in surface water samples

Parameter	Min.	Max.	Mean ± SD
Temperature (°C)	15.03	24.40	18.55 ± 2.65
pH	7.92	8.36	8.10 ± 0.07
Turbidity (FNU)	2.44	28.75	11.02 ± 4.72
Total Dissolved Solids (TDS mg/L)	207.56	280.80	249.47 ± 19.02
Conductivity (µS/cm)	262.53	411.56	337.56±41.75
Dissolved Oxygen (ODO mg/L)	7.01	9.43	8.06 ± 0.55
Oxygen Saturation (ODO % sat)	78.94	94.91	85.93 ± 3.09
Oxidation-Reduction Potential (ORP mV)	-26.59	238.79	122.69 ± 59.28
Salinity (PSU)	0.15	0.21	0.18 ± 0.01
Nitrate (NitraLED mg/L)	2.67	101.82	12.80 ± 12.71
Chlorophyll (RFU)	0.27	1.49	0.48 ± 0.16
Total Algal Content (TAL - PC RFU)	0.01	1.91	0.69 ± 0.41
Total Flow Rate (m^3/s)	1368.31	7750.719	6196.83 ± 1339.17

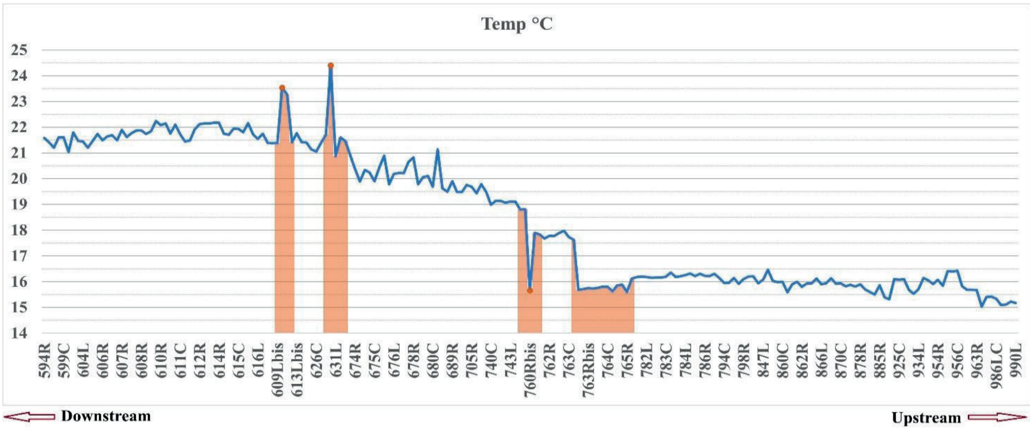

Figure 3. Evolution of the Temperature (°C) indicator in investigated surface water samples

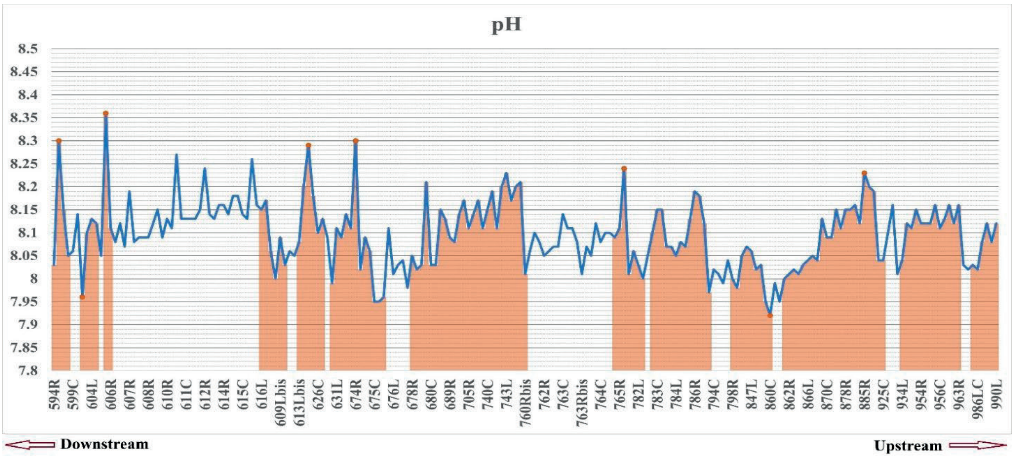

Figure 4. Evolution of the pH indicator in the investigated surface water samples

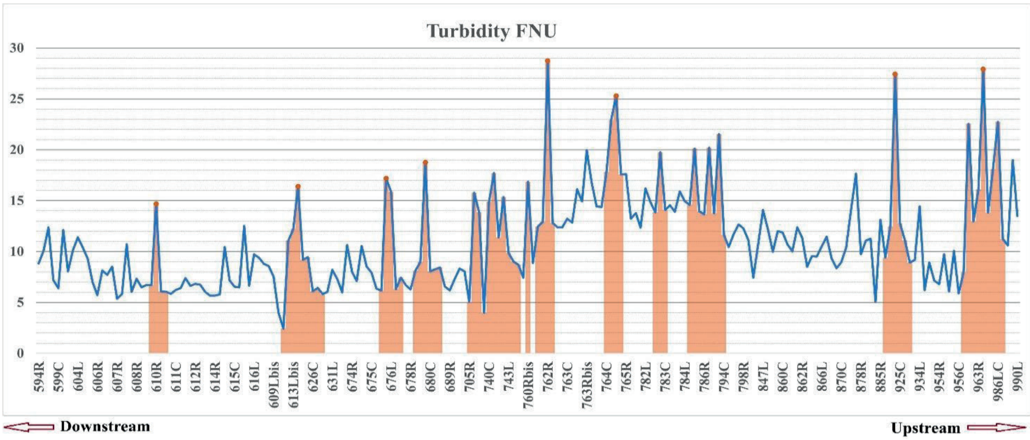

Figure 5. Evolution of the Turbidity (FNU) indicator in the investigated surface water samples

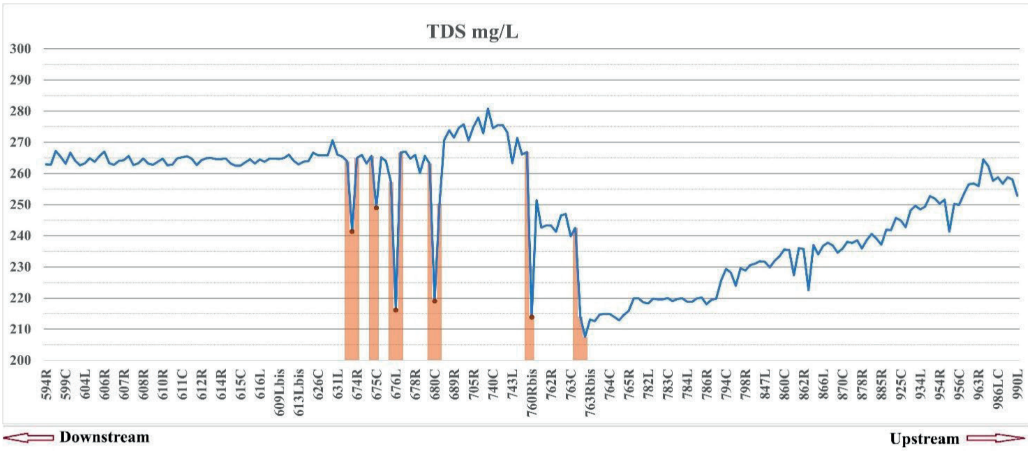

Figure 6. Evolution of the TDS (mg/L) indicator in the surface water samples investigated

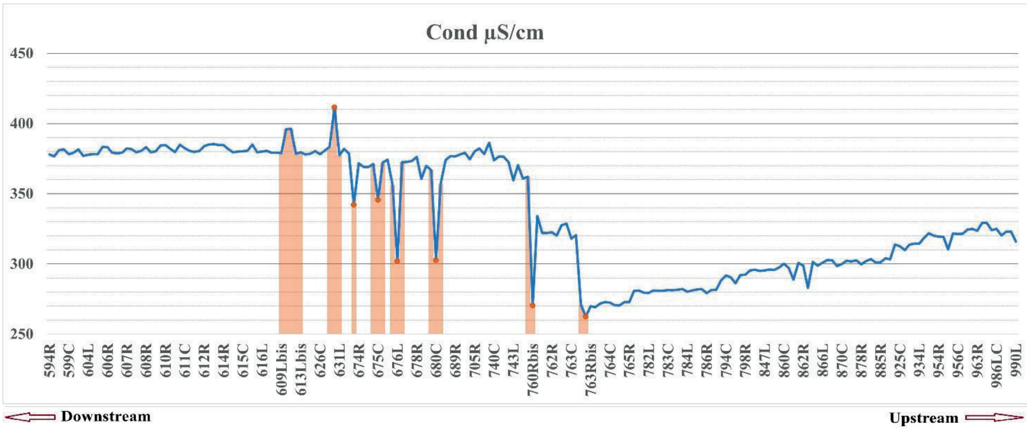

Figure 7. Evolution of the Conductivity (µS/cm) indicator in the investigated surface water samples

The dissolved oxygen regime (mg/l). The dissolved oxygen (DO) concentrations confirmed that the investigated waters belong to the well-oxygenated surface water category (quality class I, ≥9 mg/L), as defined by Order 161/2006. All measured values were above the 5 mg/L threshold, which is the minimum recommended concentration to support aquatic life (www.niwa.co.nz). Measured DO concentrations ranged from 7.01 to 9.43 mg/L, with an average of 8.06 mg/L. The lowest concentration was recorded at km 610 Bis left bank, while the highest was observed at km 762 Bis right bank. Oxygen saturation levels ranged from 78.94% to 94.91%, confirming good aeration and the absence of significant hypoxic conditions (Figure 8). These findings highlight stable oxygen levels, ensuring adequate conditions for aquatic ecosystems.

The *oxidation-reduction potential* (ORP) values indicate that the tested water is in good condition, falling within the typical range for natural waters (-500 to +700 mV) (Chapman, 1996; Sigg, 2000). The oxidation-reduction potential (ORP) ranged from -26.59 to 238.79 mV, with a mean of 122.69 mV, the lowest value recorded at km 674 center, and the highest at km 763 center. The presence of both positive and negative values suggests dynamic redox conditions influenced by organic matter decomposition, microbial activity, and oxygen availability. These variations reflect localized environmental factors that regulate oxidation-reduction processes in the Danube's aquatic system (Figure 9).

Salinity values (0.15-0.21 PSU, mean 0.18) confirm the freshwater nature of the Danube, in agreement with previous studies. Low salinity levels reflect limited seawater intrusion or evaporative concentration effects. These values indicate fresh surface waters, with low salinity (salinity below 0.5‰), (Montagna et al., 2013) characteristic of the fluvial and lacustrine domain.

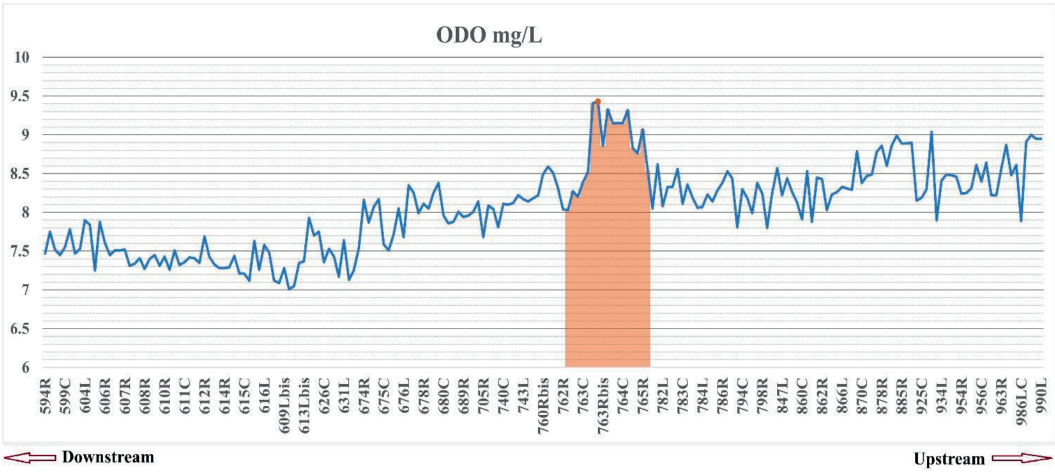

Figure 8. Evolution of the ODO (mg/L) indicator in the investigated surface water samples

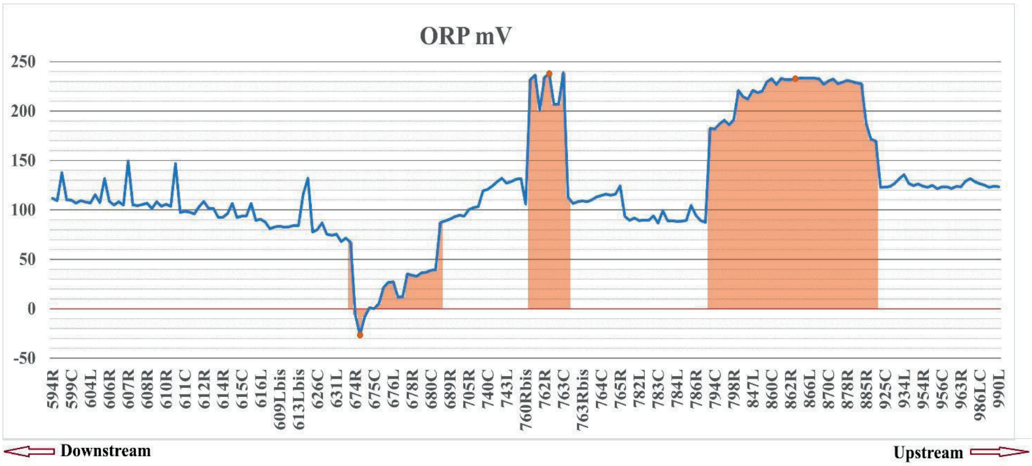

Figure 9. Evolution of the ORP (mV) indicator in the investigated surface water samples

The *NitraLED (mg/L)* values indicate significant variations in nitrate concentrations at different measurement points. The Nitrate concentrations (mg/L) ranged from 2.67 to 101.82 mg/L, with a mean of 12.80 mg/L. The highest value recorded was 101.82 mg/L at km 956 right bank, followed by 92.56 mg/L at km 925 central and 80.45 mg/L at km 677 right bank. These levels are significantly higher than the rest of the measurements and may indicate local sources of nitrate pollution. Other significantly elevated values include 74.19 mg/L (km 866 left bank), 53.69 mg/L (km 608 left bank), and 52.73 mg/L (km 638 central).

Most measurements range between 10 and 20 mg/L, which is relatively common for surface waters affected by anthropogenic activities. For example, at km 594, concentrations are relatively constant between 14.8 and 15.54 mg/L, suggesting a stable source of nitrates in this area. The lowest concentrations are found in the range of 4 to 7 mg/L, such as km 844 central (4.29 mg/L), km 798 right bank (4.07 mg/L) and km 794 central (4.32 mg/L). These values may indicate areas less affected by agricultural activities or industrial discharges (Figure 10).

High nitrate levels may be associated with agricultural discharges (fertilizers), wastewater or natural sources (organic remineralization).

Sudden increases in certain locations (e.g. km 956 md) suggest localized contamination.

Chlorophyll RFU values ranged from 0.27 to 1.49 (mean 0.48), remaining well below the 25 µg/L threshold for quality class I, which indicates low phytoplankton biomass and minimal risk of eutrophication. The lowest value was recorded at km 762 left bis. The highest value was observed at km 638 (left bank). These results suggest stable trophic conditions, with no significant algal blooms detected, supporting a balanced aquatic ecosystem (Figure 11).

Total Algal Content (TAL - PC RFU) values ranged from 0.01 to 1.91 (mean 0.69). High values (RFU > 1.0) were recorded in the Calnovat areas (km 604-616): km 609 center (1.46), km 609 right bank (1.33); Corabia (km 631 left bank): 1.58 (strong local input from the grain port); Bogdan Seclan (km 781-786): km 783 center (1.91); Drobeta Turnu-Severin (km 925-934): km 934 left bank (1.39), km 935 center (1.37); Orșova and surroundings (km 951-954): km 951 center (1.37), km 954 left bank (1.54); Iron Gates II area (km 860-878): km 878 center (1.5); Eșelnița–Dubova: km 971 center (1.1) (Figure 12). These values suggest intense anthropogenic influences, particularly related to port, industrial, urban and tourist activities.

Medium values (RFU between 0.3 and 1.0) were recorded in the areas such as Zimnicea (km 594): 0.58 (moderate urban impact); Bechet (km 674-678): 0.13-0.55 (low to moderate impact); Pisculet Desa (km 760 center): 0.97 (significant local variation, local moderate influences);

Bogdan Seclan (km 781-786): most values between 0.3 and 0.9, reflecting local moderate to high impact. Instead, low values (RFU < 0.3) were recorded at Zimnicea (km 599 upstream): 0.08-0.13 (low anthropogenic influence); Corabia (km 626-631 centru/right bank): 0.01-0.06 (clean, uncontaminated areas); Pisculet Desa (km 760 left bank): 0.1 (minimal local impact). These values indicate relatively clean areas, with little or no anthropogenic impact.

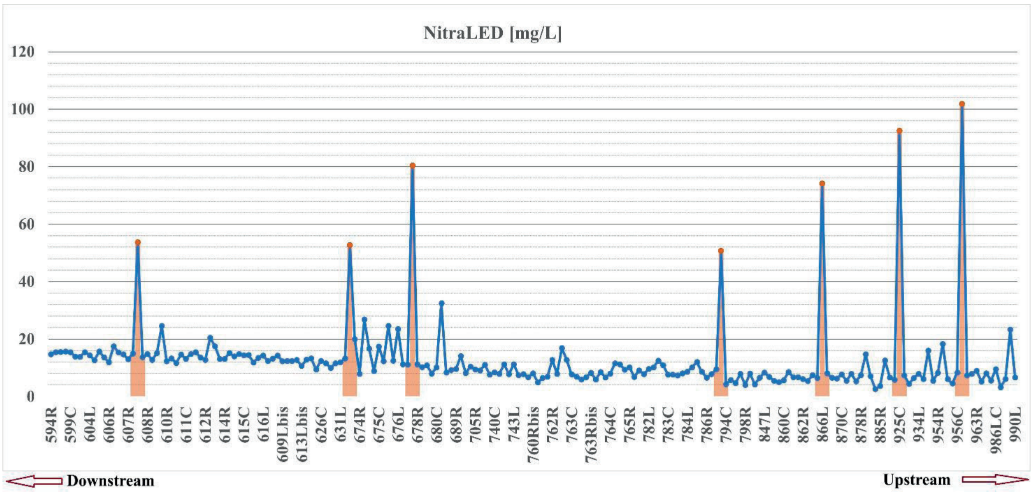

Figure 10. Evolution of the NitraLED (mg/L) indicator in the investigated surface water samples

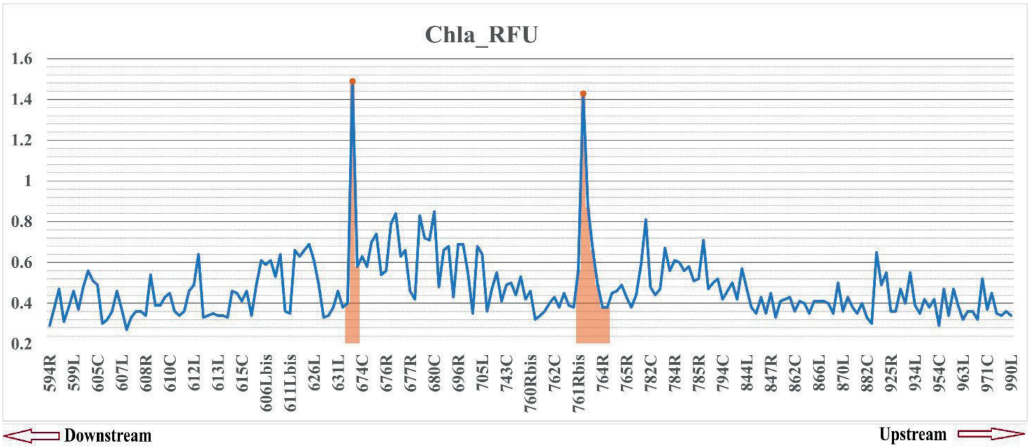

Figure 11. Evolution of the Chlorophyll RFU indicator in the investigated surface water samples

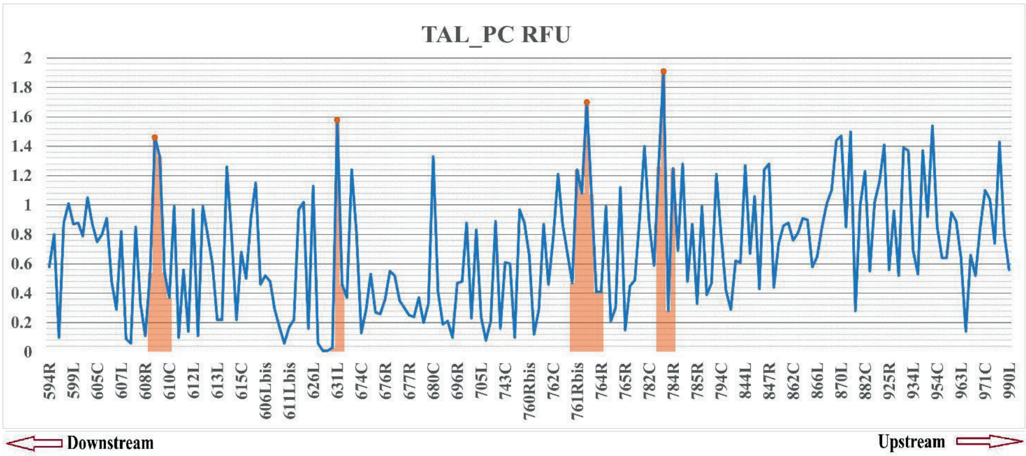

Figure 12. Evolution of the TAL_PC RFU indicator in the investigated surface water samples

Hydrocarbon contamination levels remained relatively low, with oil-in-water concentrations ranging from 0.03 to 1.46 mg/L (mean 0.44 mg/L) and hydrocarbon (HC) concentrations between 0.89 and 48.70 µg/L (mean 14.74 µg/L). The highest hydrocarbon levels were detected at km 675 (right bank) in the Bechet Sector, suggesting possible localized sources of pollution. However, despite these findings, overall concentrations remained below critical thresholds for significant environmental risk, indicating no immediate threat to water quality (Table 2, Figures 13 and 14).

Table 2. Hydrocarbon concentrations of water surface samples

Parameter	Oil in Water (mg/L)	Hydrocarbons (HC) (µg/L)	Custom#3 (mg/L)
Minimum	0.03	0.89	0.41
Maximum	1.46	48.70	48.70
Mean ± SD	0.44 ± 0.17	14.74 ± 5.67	14.27 ± 6.14

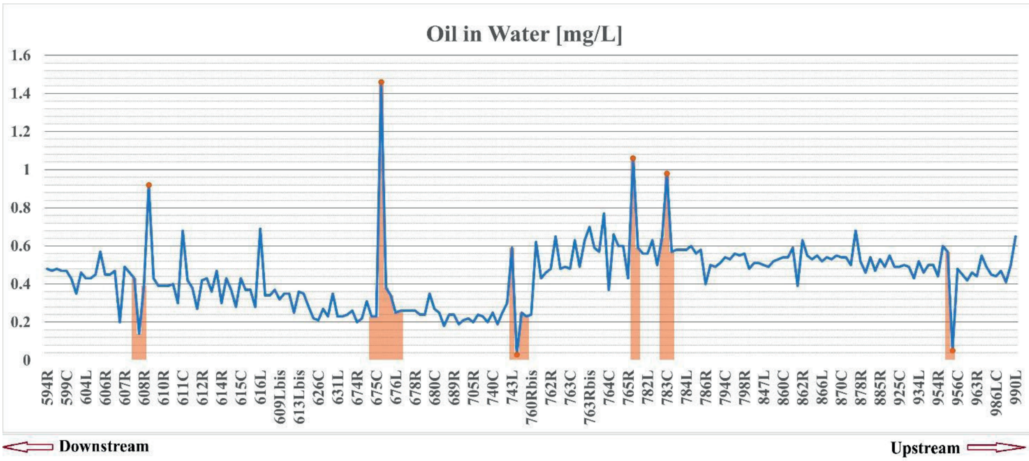

Figure 13. Evolution of the Oil in water (mg/l) indicator in the investigated surface water samples

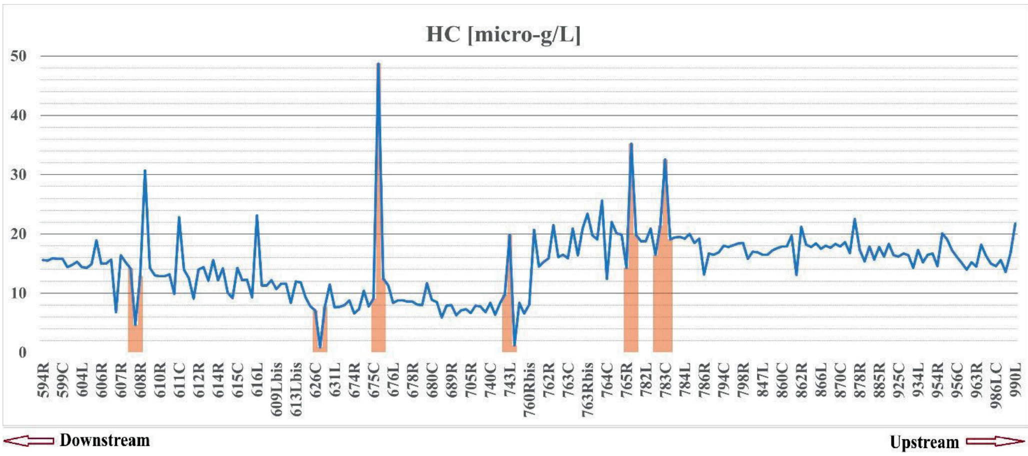

Figure 14. Evolution of the HC (micro-g/l) indicator in the investigated surface water samples

The values of the monitored physicochemical parameters were generally within the limits allowed by environmental standards, reflecting a good state of water quality in the analyzed sectors of the Danube (Pavlović et al., 2016; Calmuc et al., 2018; Radu et al., 2022).

The *water temperature* varied between 15.03°C (km 968, left bank) and 24.40°C (km 631, center), with an overall average of 18.55°C, reflecting natural seasonal influences specific to autumn. These variations can influence biological activity, metabolism of aquatic organisms and solubility of dissolved oxygen in water.

pH values ranging from 7.92 (km 860 center) to 8.36 (km 605 right bank), with an average of 8.10, indicate a slightly alkaline state of the water, characteristic of aquatic systems with high buffer capacity, due to the carbonate-bicarbonate balance present in the Danube River. No significant acidification or alkalization events were identified.

Water turbidity showed significant variations, with values between 2.44 FNU (Km 610, left bank, Calnovăț sector) and 28.75 FNU (km 762 right bank Pisculet-Desa Sector), with an average of 11.02 FNU. Values exceeding the standard limit of 10 NTU (ISO 5667-5:2017) indicate increased local sediment input or intense resuspension processes, especially at km 762 right bank, while low turbidity (km 610 left bank) reflects areas with increased sedimentation or reduced suspended sediment flux.

TDS concentration values ranged between 207.56 mg/L (km 762 right bank) and 280.80 mg/L (km 740, right bank), with an average of 249.47 mg/L. These values reflect a moderate influence of dissolved salts, indicating good quality water, without significant contamination from upstream.

The *water conductivity* had values between 262.53 µS/cm and 411.56 µS/cm (km 631 center), with an average of 337.56 µS/cm. The higher conductivity in the km 631 - Upstream Corabia/Downstream River Isker, area suggests local influences, possibly geological or anthropogenic, but generally confirms the typical characteristics of freshwaters, with moderate mineralization.

Dissolved oxygen concentration ranged from 7.01 mg/L (km 610 bis left bank) to 9.43 mg/L (km 762 right bank), with an overall average of 8.06 mg/L, above the recommended minimum limit (5 mg/L) for aquatic life support. However, some points with lower values suggest intense biological activity or localized organic matter input.

Oxygen saturation levels ranged from 78.94% to 94.91%, indicating good overall water aeration and the absence of extensive hypoxic conditions. Lower values may indicate point sources of organic pollution or active local microbial processes.

The measured *ORP values* ranged from -26.59 mV (km 674 center) to 238.79 mV (km 763 center), with an average of 122.69 mV. The presence of both positive and negative values suggests complex dynamics of the redox environment, influenced by organic matter decomposition, microbial activity and oxygen availability. The negative values observed in the Bechet sector (km 674 right bank to km 674 left bank) indicate possible local anoxic conditions, related to organic matter decomposition or reducing groundwater inputs.

The *water salinity* remained low (between 0.15 and 0.21 PSU, average 0.18 PSU), confirming the freshwater characteristics of the Danube and indicating the lack of significant influences from seawater or intense evaporative processes.

Nitrate concentrations varied significantly (between 2.67 and 101.82 mg/L), with an average of 12.80 mg/L. Very high values were identified at km 956 (101.82 mg/L), km 925 center (92.56 mg/L) and Km 677, Bechet Sector (80.45 mg/L), indicating possible local sources of contamination (agricultural runoff, urban wastewater). Most of the average values (10-20 mg/L) suggest moderate anthropogenic influences, while low values (4-7 mg/L) indicate areas with low impact.

Chlorophyll values were low (0.27-1.49 RFU, mean 0.48 RFU), reflecting a low phytoplankton biomass and minimal risk of eutrophication. Moderate peaks (km 638, left bank, (Upstream of Isker River) suggest local algal blooms caused by nutrient inputs.

Total Algae Content (TAL-PC RFU). Algal indicators showed significant variations (between 0.01-1.91 RFU, average 0.69 RFU). High values (>1.0 RFU) indicate significant anthropogenic influences in the areas of Calnovăţ, Corabia, Bogdan Seclan, Drobeta-Turnu Severin, Orșova and the area of Iron Gate Dam II. Medium values (0.3-1.0 RFU) reflect moderate impacts in other urban and port areas, and low values (<0.3 RFU) suggest clean areas, without notable anthropogenic influences.

Polycyclic aromatic hydrocarbons and total hydrocarbons. The level of hydrocarbons (0.89-48.70 µg/L HC and 0.03-1.46 mg/L Oil in Water) was relatively low, with moderate peaks in the Bechet sector (km 675). Although indicating the presence of local sources of contamination, the values are below the critical thresholds, suggesting the absence of an immediate ecological risk.

Data analysis using the Pearson correlation matrix indicates statistically significant relationships at a significant level of $\alpha = 0.05$, as shown in Table 3 and Figure 15.

Positive correlations:

- Electrical conductivity (Cond µS/cm) and total dissolved solids (TDS mg/L): Strong positive correlation (r=0.943), confirming that TDS directly depends on the ionic concentration of water, reflected by conductivity.
- Hydrocarbons (HC µg/L) and oil concentration in water (Oil in Water mg/L): Very strong positive correlation (r=0.974), suggesting that hydrocarbons contribute significantly to the total oil concentration in water, indicating common sources, possibly local oil pollution.
- Conductivity and Salinity (Sal psu): Significant positive correlation (r=0.911),

indicating a clear link between the total dissolved salt concentration and water conductivity.

- Conductivity and Water Temperature: Positive correlation (r=0.694), which may indicate that temperature variations significantly influence ionic concentrations and implicitly water conductivity.
- Oxygen Saturation (ODO % sat and ODO mg/L): Moderate to high positive correlation (r=0.632), signaling the consistency of these measurements in reflecting the concentration of dissolved oxygen in water.

Negative correlations:

- Temperature and Dissolved Oxygen (ODO mg/L): Strong negative correlation (r=-0.847), indicating that higher temperatures lead to lower concentrations of dissolved oxygen, a common fact in aquatic systems.
- Temperature and Redox Potential (ORP mV): Significant negative correlation (r=-0.517), with higher temperatures being associated with reduced redox conditions, reflecting a change in chemical conditions due to temperature.
- Electrical Conductivity and Dissolved Oxygen (ODO mg/L): Strong negative correlation (r=-0.764), indicating that waters with high conductivity (possibly with inputs of inorganic pollutants or salts) have low dissolved oxygen concentrations.

Based on the Euclidian similarity index (Figure 16), it can be observed that as the total flow rate increases, the percentage of oxygen saturation tends to decrease moderately, while the concentration of dissolved oxygen in mg/L is almost unaffected. In stations km 761 bis right bank and km 762 bis right bank, where a very low flow was recorded, due to their location after the ostrov, in an area with weaker currents and reduced depth, high dissolved oxygen concentrations, low TDS values and lower water temperatures were recorded.

Table 3. Correlation matrix (Pearson)

Variables	Chlorophyll RFU	Cond µS/cm	ODO % sat	ODO mg/L	ORP mV	Sal psu	TAL PC RFU	TDS mg/L	Turbidity FNU	pH	Temp °C	NitraLED mg/L	HC micro -g/L	Oil in water mg/L
Chlorophyll RFU	**1**	-0.071	**0.168**	0.048	**-0.390**	**-0.161**	0.105	**-0.151**	0.134	-0.049	0.043	-0.039	-0.121	-0.118
Cond µS/cm	-0.071	**1**	-0.092	**-0.764**	**-0.452**	**0.911**	**-0.368**	**0.943**	**-0.563**	**0.292**	**0.913**	**0.167**	**-0.530**	**-0.519**
ODO % sat	**0.168**	-0.092	**1**	**0.632**	-0.119	-0.014	0.012	-0.055	**0.167**	**0.333**	-0.126	-0.110	-0.045	-0.058
ODO mg/L	0.048	**-0.764**	**0.632**	**1**	**0.345**	**-0.554**	**0.289**	**-0.601**	**0.518**	-0.006	**-0.847**	**-0.194**	**0.341**	**0.322**
ORP mV	**-0.390**	**-0.452**	-0.119	**0.345**	**1**	**-0.331**	**0.276**	**-0.343**	**0.162**	-0.098	**-0.517**	**-0.164**	**0.312**	**0.312**
Sal psu	**-0.161**	**0.911**	-0.014	**-0.554**	**-0.331**	**1**	**-0.339**	**0.973**	**-0.499**	**0.296**	**0.694**	**0.158**	**-0.505**	**-0.505**
TAL PC RFU	0.105	**-0.368**	0.012	**0.289**	**0.276**	**-0.339**	**1**	**-0.325**	**0.193**	0.024	**-0.360**	-0.038	**0.266**	**0.258**
TDS mg/L	**-0.151**	**0.943**	-0.055	**-0.601**	**-0.343**	**0.973**	**-0.325**	**1**	**-0.500**	**0.298**	**0.726**	**0.144**	**-0.525**	**-0.519**
Turbidity FNU	0.134	**-0.563**	**0.167**	**0.518**	**0.162**	**-0.499**	**0.193**	**-0.500**	**1**	-0.100	**-0.552**	-0.113	**0.277**	**0.276**
pH	-0.049	**0.292**	**0.333**	-0.006	-0.098	**0.296**	0.024	**0.298**	-0.100	**1**	**0.236**	-0.086	**-0.145**	**-0.144**
Temp °C	0.043	**0.913**	-0.126	**-0.847**	**-0.517**	**0.694**	**-0.360**	**0.726**	**-0.552**	**0.236**	**1**	**0.173**	**-0.455**	**-0.439**
NitraLED mg/L	-0.039	**0.167**	-0.110	**-0.194**	**-0.164**	**0.158**	-0.038	**0.144**	-0.113	-0.086	**0.173**	**1**	-0.113	-0.105
HC_micro-g/L	-0.121	**-0.530**	-0.045	**0.341**	**0.312**	**-0.505**	**0.266**	**-0.525**	**0.277**	**-0.145**	**-0.455**	-0.113	**1**	**0.974**
Oil in water mg/L	-0.118	**-0.519**	-0.058	**0.322**	**0.312**	**-0.505**	**0.258**	**-0.519**	**0.276**	**-0.144**	**-0.439**	-0.105	**0.974**	**1**

Values in bold are different from 0 with a significance level alpha=0.05

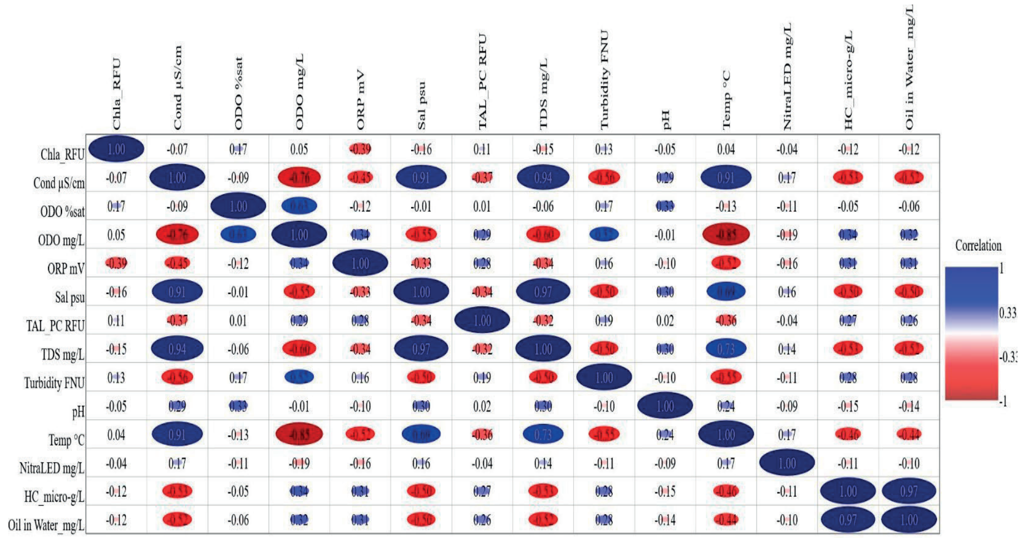

Figure 15. Correlation matrix (Pearson)

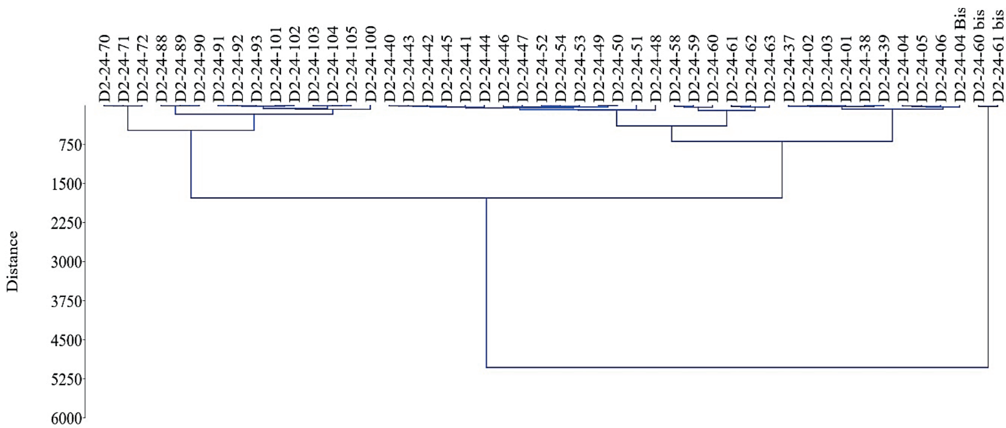

Figure 16. Similarity index based on Euclidian transformed data

Possible causes and ecological implications

Agricultural runoff: high nitrate and turbidity levels suggest significant inputs of fertilizers or animal manure.

Urban/industrial pollution: atypical values of conductivity, TDS and ORP may indicate anthropogenic influences, such as wastewater discharges.

Geological factors: variability of TDS, conductivity and ORP could be influenced by inputs of mineralized groundwater.

The results indicate that the investigated Danube River sectors generally maintain good water quality, parameters that fall within regulatory standards. However, localized variations in turbidity, dissolved oxygen and hydrocarbon levels highlight the importance of continuous monitoring to detect potential environmental stressors and anthropogenic impacts (Chitescu et al., 2021; Halder et al., 2022).

In order to determine the water quality status of the investigated control sections, a series of physicochemical parameters were taken into account (water temperature, pH, dissolved oxygen chlorophyll *a*, electrical conductivity, total dissolved solids, salinity, turbidity and oxidation-reduction potential).

The determination and interpretation of the results obtained was carried out using the methods provided in the reference standards.
In general, no significant increases/decreases were recorded, except for some specific cases, which can be attributed mainly to the local conditions of the fluvial environment.
Overall, the results obtained are within the limits provided for the first quality classes (Very good status and good status).

CONCLUSIONS

Comprehensive analysis of water quality parameters - temperature, pH, turbidity, total dissolved solids (TDS), conductivity, dissolved oxygen (ODO), oxygen saturation, oxidation-reduction potential (ORP), salinity, nitrates, chlorophyll levels, total algal content and hydrocarbons - indicates generally favorable conditions in the investigated areas of the lower Danube, though localized areas of concern have been identified.
These localized problems, such as high nitrate concentrations, increased turbidity, occasional anoxic conditions and high algal fluorescence, highlight critical anthropogenic pressures mainly related to agricultural runoff, urban wastewater discharges, port operations and other local sources. Although current concentrations remain largely below critical ecological thresholds, persistent anthropogenic pressures may compromise water quality and ecosystem stability if not managed.
Therefore, these findings highlight the need for targeted monitoring and mitigation actions, especially around urban centers, the port and agricultural areas, to prevent long-term deterioration of water quality. Ensuring consistent and high-quality water in the Danube basin is vital for supporting biodiversity, preserving ecological balance and supporting the socioeconomic well-being of riparian communities dependent on river resources. These insights highlight the need for proactive environmental management strategies, targeted pollution control and continuous monitoring to protect the health of the Danube ecosystem and its resilience against future anthropogenic pressures.

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