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ASSESSMENT OF NUTRIENTS IN THE DANUBE RIVER AND THEIR IMPACT ON WATER QUALITY IN THE BRĂILA SECTOR

Nicoleta CIOBOTARU
“Dunarea de Jos” University of Galati, Faculty of Engineering and Agronomy,
Calarasi Street, 29, RO-810017, Braila, Romania
e-mail: nicoleta.ciobotaru@ugal.ro

ABSTRACT

This study analyses the water quality of the Danube River in the Brăila sector by evaluating key nutrients and relevant physicochemical parameters. The concentrations of nitrogen compounds (nitrates, nitrites, ammonium) and phosphorus compounds (phosphates) were determined, along with parameters such as pH, total dissolved solids (TDS), dissolved oxygen, and biochemical oxygen demand (BOD_5). For a more comprehensive assessment of water quality, chloride and sulphate ions were additionally analysed as indicators of mineralization and anthropogenic influences. The obtained results were compared with the reference values established by current national legislation. The analysed parameters indicate good water quality, with no major signs of organic pollution; however, the presence of nutrients may, under certain conditions, promote eutrophication processes. The findings contribute to the assessment of the ecological status of the water and highlight the importance of continuous monitoring of quality parameters in order to prevent the degradation of aquatic ecosystems and to ensure sustainable water resource management.

KEYWORDS: Danube, nutrients, nitrates, phosphates, eutrophication, water quality

1. Introduction

The Danube River has a particular importance at the European level, as it flows through numerous countries and represents a key element in regional development and biodiversity conservation. Surface water quality is an essential indicator of the health status of aquatic ecosystems, and its monitoring is necessary for the prevention and control of pollution.

Among the main parameters used in water quality assessment are nutrients, especially nitrogen and phosphorus compounds. These are essential for the growth of aquatic organisms; however, at high concentrations, they may lead to significant ecological imbalances [1]. The increase in nutrient concentrations in surface waters is frequently associated with anthropogenic activities, such as intensive agriculture and industrial activities [2].

Agricultural activities within the Danube River Basin, particularly through the use of chemical fertilizers whose components (nitrogen and phosphorus) are transported into surface waters via diffuse runoff and leaching processes, represent a major source of nutrient input. Domestic wastewater constitutes another important source of nutrients in surface waters, due to its nitrogen and phosphorus content originating from organic matter and household products, including detergents and cleaning agents. In particular, phosphates used in detergent formulations contribute to the nutrient loading of receiving waters, intensifying eutrophication processes under conditions of insufficient or inefficient urban wastewater treatment [3]. The eutrophication process is characterized by excessive growth of phytoplankton and algae, reduced water transparency, and consequently a decrease in dissolved oxygen concentration [4]. This phenomenon can have severe consequences for aquatic ecosystems, leading to the mortality of aquatic organisms and the degradation of water quality [5].

In addition, navigation along the Danube River represents another anthropogenic factor that may influence the physicochemical parameters of water. Shipping activities can locally contribute to sediment resuspension, increased turbidity, and potential inputs of pollutants (oils, hydrocarbons, residual

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compounds), which may cause localized changes in ion concentrations and water quality indicators, particularly in areas with intense river traffic [6].

Throughout its European course, the Danube River flows through numerous countries and capital cities, progressively accumulating various natural and anthropogenic loads from the river basins it traverses. Although rivers exhibit a natural self-purification capacity through physical, chemical, and biological processes, these do not lead to a complete reduction of the pollutant load [7].

Consequently, the Danube River is subjected to significant pressures generated by human activities within its extensive catchment area, which includes agricultural, urban, and industrial regions. Monitoring these quality indicators is essential for assessing the ecological status of water and for implementing appropriate management measures.

The aim of the present study is to evaluate the nutrient levels in the Danube River, in the Brăila sector, by determining the main nitrogen compounds (nitrates, nitrites, ammonium) and phosphorus compounds (phosphates), as well as analysing their impact on water quality. The obtained results are interpreted in relation to the limits established by the current legislation, in order to determine the water quality status and to identify potential sources of pollution. This analysis aims to highlight the importance of nutrient monitoring in surface waters and to contribute to a better understanding of the processes influencing water quality in the Danube River.

2. Materials and methods

2.1. Study area

Throughout its European course, the Danube River flows through numerous countries and capital cities, progressively accumulating various natural and anthropogenic loads from the river basins it traverses. Located near its discharge into the Black Sea, the lower sector represents a final stage of integration and transformation of the river's water composition [8].

In the Brăila sector, the Danube River forms a complex fluvial ecosystem, characterized by a wide floodplain, secondary channels, and wetlands with high biodiversity.

In this region, the river significantly influences sediment dynamics and the local hydrological regime, playing an essential role in landscape formation. At the same time, the river sector in the Brăila area is of both ecological and socio-economic importance, being used for water supply, fishing, and adjacent agricultural activities.

2.2. Sampling

Water samples were collected from a representative point of the Danube River, located near the riverbank, in a sector with moderate anthropogenic influence, namely the riverside promenade area (Figure 1). Sampling was carried out in spring, during the month of May, and the water temperature at the time of collection was 16 °C.

The samples were collected in clean glass containers, previously rinsed with water from the sampling site to avoid contamination. The samples were transported under controlled conditions and analysed as soon as possible in order to minimize physicochemical changes.

Fig. 1. *Sampling area* [9]

2.3. Analytical parameters

Within the study, a set of parameters was determined in order to assess both the eutrophication status of the water and its overall physicochemical quality.

The experimental determinations were carried out using standard laboratory methods, as follows:

- pH was determined using the potentiometric method;

- total dissolved solids (TDS) were determined using the conductometric method;

- dissolved oxygen was determined using the Winkler method;

- biochemical oxygen demand (BOD_5) was determined by incubation at 20 °C for 5 days;

- nitrates, nitrites, ammonium, phosphates, chlorides, and sulphates were determined spectrophotometrically.

2.4. Results interpretation

The obtained results were interpreted in accordance with the provisions of Order 161/2006, which establishes the classification of surface waters into five quality classes based on physicochemical and biological parameter values.

The classification of each parameter was carried out by comparing the experimental values with the corresponding limits of the quality classes presented in Table 1, in order to assess the ecological status of the water (Class I represents the highest quality and Class V the lowest quality).

Table 1. *Permitted quality classes for surface waters (mg/L)* [10]

Indicator	Class I	Class II	Class III	Class IV	Class V
pH	6.5–8.5	6.0–9.0	5.5–9.5	5.0–10.0	<5 or >10
Dissolved oxygen	≥ 9	≥ 7	≥ 5	≥ 4	< 4
BOD_5	≤ 3	≤ 5	≤ 7	≤ 20	> 20
Nitrates (NO_3^-–N)	≤ 1.0	≤ 3.0	≤ 5.6	≤ 11.2	> 11.2
Nitrites (NO_2^-–N)	≤ 0.01	≤ 0.03	≤ 0.06	≤ 0.30	> 0.30
Ammonium (NH_4^+–N)	≤ 0.40	≤ 0.80	≤ 1.20	≤ 3.2	> 3.2
Phosphates (PO_4^{3-}–P)	≤ 0.10	≤ 0.20	≤ 0.40	≤ 0.90	> 0.90
Chlorides (Cl^-)	≤ 25	≤ 50	≤ 250	≤ 300	> 300
Sulfates (SO_4^{2-})	≤ 60	≤ 120	≤ 250	≤ 300	> 300
Total dissolved solids (TDS)	≤ 500	≤ 750	≤ 1000	≤ 1500	> 1500

3. Results and Discussion

The results of the performed analyses are presented in Table 2, both for the physicochemical parameters and for the nutrients in the sampled Danube water.

Table 2. *Variation of the studied water quality indicators in the Danube River (mg/L)*

Indicator	Obtained values
pH	7.21
Dissolved oxygen	12.8
BOD_5	2.8
Nitrates (NO_3^-–N)	1.67
Nitrites (NO_2^-–N)	0.02
Ammonium (NH_4^+–N)	1.25
Phosphates (PO_4^{3-}–P)	0.2
Chlorides (Cl^-)	38
Sulfates (SO_4^{2-})	20
Total dissolved solids (TDS)	332

3.1. Physicochemical parameters

The results obtained from the physicochemical analyses of the Danube River water in the Brăila sector revealed variations in the main investigated parameters. The measured pH value was 7.21, indicating a slightly alkaline reaction, characteristic of natural surface waters [11]. This range falls within the permissible limits for good-quality waters according to Order 161/2006 (6.5-8.5), suggesting the absence of significant acidification or excessive alkalinization processes (Figure 2).

The total dissolved solids (TDS) concentration was 332 mg/L, indicating a moderate level of water mineralization (Figure 3). This value is below the 500 mg/L threshold specific to very good and good-quality waters, suggesting a limited anthropogenic influence on the ionic composition of the water in the studied sector [12].

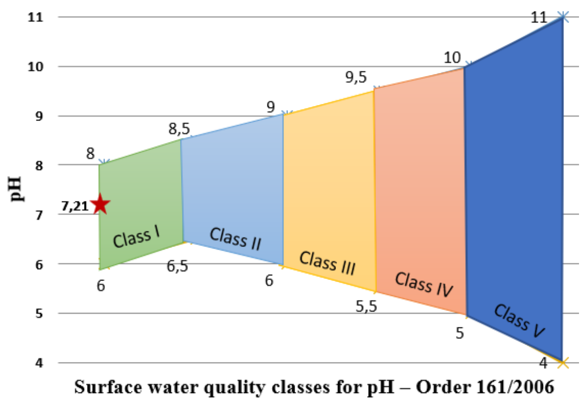

Fig. 2. *The pH concentration in relation to the permissible limits*

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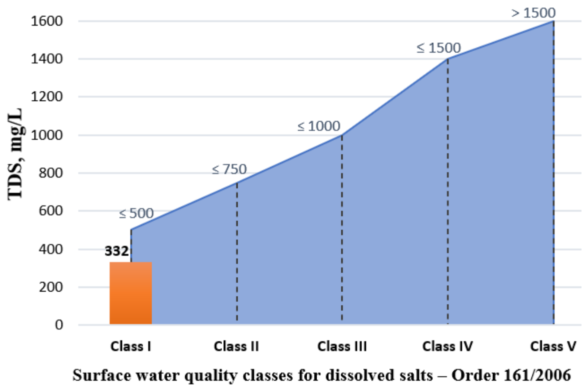

***Fig. 3.** The TDS concentration in relation to the permissible limits*

At a water temperature of approximately 16 °C, the solubility of oxygen in water is relatively high (around 9-10 mg/L at saturation); however, the measured value (12.8 mg/L) indicates oxygen supersaturation of the water (Figure 4). This phenomenon is commonly observed in the spring season and may be associated both with intense phytoplanktonic and macrophyte photosynthesis processes and with enhanced aeration due to the hydrodynamic regime (increased discharge, turbulence) [13]. The high level of dissolved oxygen reflects good oxygenation conditions and favourable environments for aquatic organisms, suggesting the absence of significant excessive biological oxygen consumption processes [14].

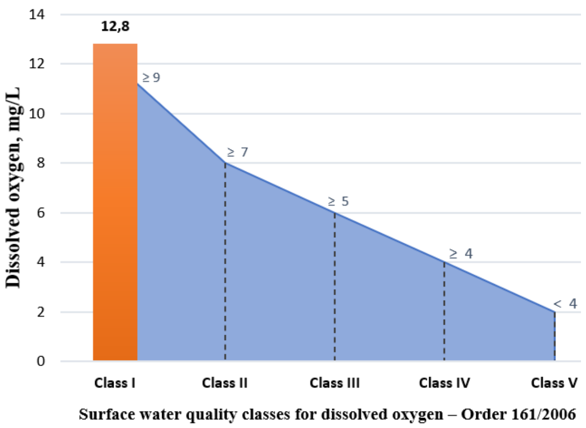

***Fig. 4.** Dissolved oxygen concentration in relation to the permissible limits*

The 5-day biochemical oxygen demand value falls within the range characteristic of surface waters with low levels of biodegradable organic matter (Figure 5). At a temperature of 16 °C, microbiological activity is moderate, and the relatively low BOD_5 value indicates that biological degradation processes do not exert significant pressure on the dissolved oxygen reservoir [15]. Correlated with the high dissolved oxygen concentration, this confirms good water quality in terms of organic pollution and a favourable balance between oxygen production and consumption [16].

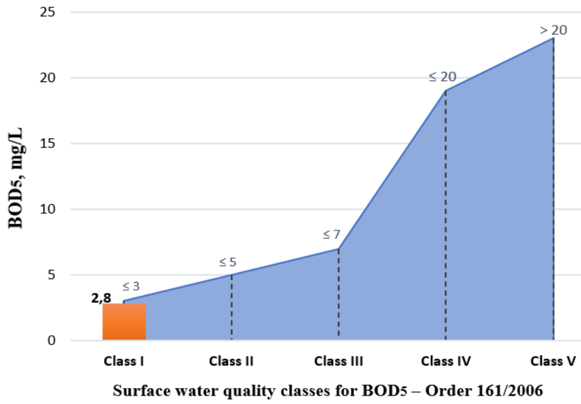

***Fig. 5.** BOD_5 concentration in relation to the permissible limits*

The chloride concentration, shown in Fig. 6, falls within the typical range for surface waters in the lower sector of the Danube River, reflecting mainly a natural mineral background, to which moderate anthropogenic contributions may be added (urban wastewater, runoff from anthropized surfaces) [16]. At relatively high discharges, characteristic of May, dilution processes limit the excessive accumulation of this ion; thus, the measured value does not indicate significant pollution pressure.

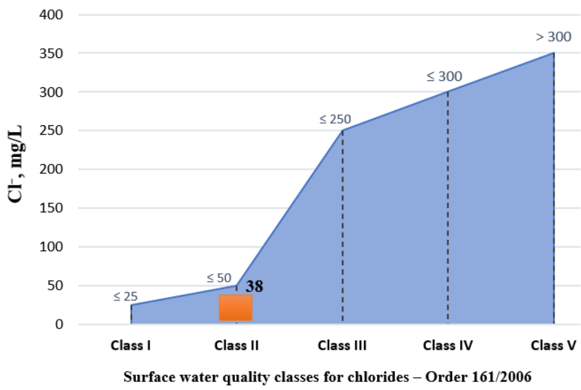

***Fig. 6.** Chlorides concentration in relation to the permissible limits*

The low sulphate concentration suggests a limited influence of industrial pollution sources or inputs derived from intense mineralization processes. Under the hydrological conditions specific to spring (increased discharge, precipitation input), low values can also be explained by the dilution effect [11].

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From a qualitative perspective, this level is characteristic of good-quality waters and indicates the absence of major sources of sulphur compound contamination (Figure 7).

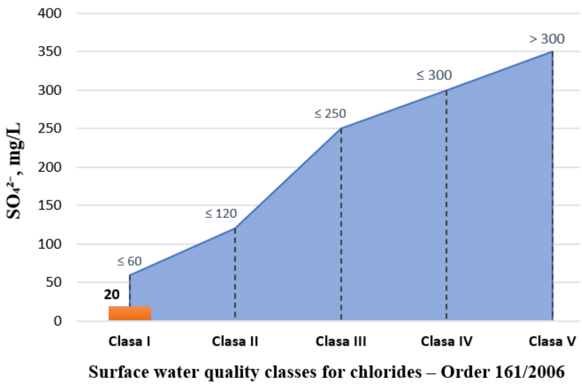

***Fig. 7.** Sulphates concentration in relation to the permissible limits*

The overall set of analysed parameters indicates well-oxygenated water, with low organic loading and moderate mineralization, characteristic of spring conditions in the lower sector of the Danube River. The correlation between oxygen supersaturation and low BOD_5 values suggests the predominance of primary production processes over biological consumption processes, while the low concentrations of the analysed ions indicate a limited anthropogenic influence during the sampling period.

3.2. Nutrient analysis

With regard to nitrogen compounds (Figure 8), the nitrate concentration ($N–NO_3^-$ = 1.67 mg/L) falls within the range characteristic of good-quality surface waters, indicating a moderate presence of nutrients mainly originating from diffuse catchment activities, such as the use of nitrogen-based fertilizers in agriculture. This value reflects nitrogen mineralization and oxidation processes without suggesting severe contamination; however, it still highlights a basin-scale anthropogenic influence [17]. The obtained result for nitrate nitrogen corresponds to Class II surface water quality [10].

The ammonium nitrogen concentration ($N–NH_4^+$ = 1.25 mg/L) indicates the presence of recent organic matter in the aquatic system, being a sensitive indicator of inputs from domestic wastewater or biological decomposition processes (Figure 9). At this level, ammonium nitrogen suggests a moderate anthropogenic influence, but not of high intensity, particularly under well-oxygenated water conditions that favour its transformation into oxidized forms (nitrites and nitrates). The obtained value falls within Class III water quality according to the official classification [10]. This result may indicate inputs of decomposing organic matter or the influence of insufficiently treated wastewater, representing a sensitive indicator of recent organic pollution [18].

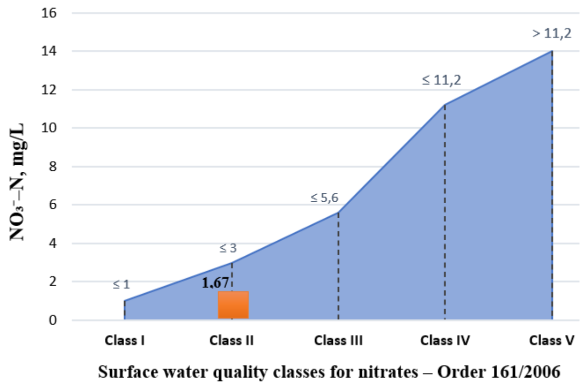

***Fig. 8.** Nitrates concentration in relation to the permissible limits*

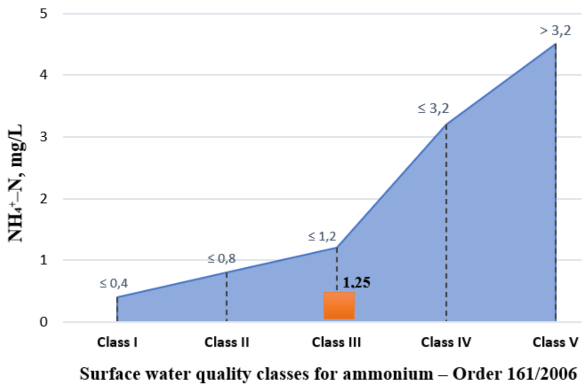

***Fig. 9.** Ammonium concentration in relation to the permissible limits*

The nitrite concentration ($N–NO_2^-$) was 0.02 mg/L, a low value characteristic of well-oxygenated surface waters (Figure 10). From a water quality classification perspective, this concentration falls within Class II according to Order 161/2006. The low nitrite level indicates efficient oxidation of intermediate nitrogen compounds towards more stable forms (nitrates), a process favoured by the observed aerobic conditions and the high dissolved oxygen concentration [12]. Thus, the obtained values suggest reduced recent sources of organic pollution and a rapid transformation of nitrogen species within the aquatic system. The phosphate concentration (PO_4^{3-}) was 0.2 mg/L (Figure 11), a value corresponding to Class II water quality according to Order 161/2006.

This concentration may reflect a moderate influence of anthropogenic sources, such as domestic wastewater or diffuse agricultural runoff, as phosphates are commonly associated with detergents

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and fertilizers [19]. Although the value does not indicate severe pollution, the presence of this nutrient above natural background levels may contribute, under favourable conditions, to the intensification of eutrophication processes, particularly during periods of elevated temperatures and reduced water flow.

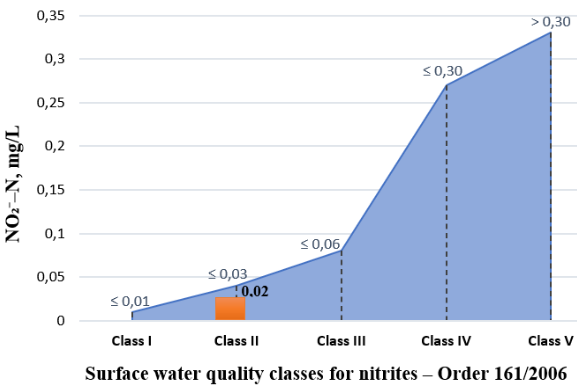

Fig. 10. *Nitrites concentration in relation to the permissible limits*

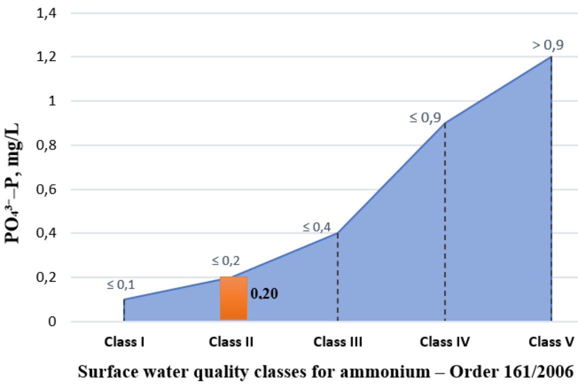

Fig. 11. *Phosphates concentration in relation to the permissible limits*

An important aspect is the existence of a wastewater treatment plant serving the municipality, which significantly contributes to the reduction of organic and nutrient loads discharged into the receiving water body. The obtained results suggest that the efficiency of the treatment processes, combined with the dilution and self-purification capacity of the Danube River, ensures the maintenance of a good ecological status in the studied sector, with no indications of advanced eutrophication or significant water quality degradation in the analysed area [20].

However, downstream of the municipality of Brăila and other urban settlements in the lower sector, the river flows in proximity to the Great Island of Brăila, an area of intensive agricultural use that contributes substantially to diffuse nutrient loading (nitrogen and phosphorus) through fertilizer application. In the context of continuous river transport, these inputs accumulate and are further transferred towards the coastal zone of the Black Sea [21].

Under favourable summer conditions (high temperature, intense solar radiation, and thermal stratification), accumulated nutrients may support intensive phytoplankton development and the occurrence of algal blooms, a phenomenon associated with riverine eutrophication [19].

Excessive and uncontrolled proliferation of marine algae has devastating effects on the environment: it leads to changes in the structure of marine animal populations, the occurrence of algal accumulations along the shoreline, and massive oxygen depletion in water, which can result in the suffocation of benthic organisms [4].

Overall, the correlation of all analysed parameters indicates water of good ecological status, characterized by moderate mineralization, high oxygenation, and low organic loading. Nutrient values suggest a present but limited anthropogenic influence, typical for a downstream river sector where dilution, transformation, and self-purification processes contribute to maintaining a relatively stable chemical balance. These results are consistent with the natural dynamics of the Danube River in its lower sector, where the river integrates inputs from the entire catchment area while still maintaining a significant capacity to attenuate pollution.

The interpretation of the results highlights the need for continuous monitoring of nutrients in the Danube River, especially in sectors influenced by agricultural and urban activities, in order to prevent the deterioration of water ecological quality.

4. Conclusions

Based on the results obtained within the study, the following conclusions regarding water quality in the Danube River in the Brăila sector can be formulated:

• The analysis of physicochemical parameters indicates an overall good water status, characterized by slightly alkaline pH (7.21) and a moderate level of mineralization (TDS = 332 mg/L), values falling within the range specific to very good-quality natural surface waters according to Order 161/2006. These results suggest the absence of significant chemical degradation processes and a relatively low anthropogenic influence on ionic composition.

• The oxygen regime indicates well-oxygenated water, with high dissolved oxygen concentrations (12.8 mg/L) and low biochemical oxygen demand (2.8 mg/L), suggesting reduced organic loading and a good self-purification capacity of the fluvial system under the analysed conditions (water temperature of

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16 °C, May). This balance reflects favourable hydrodynamic conditions and controlled biological activity.

• The low concentrations of nitrites and sulphates, as well as the moderate level of chlorides, confirm the absence of major point-source pollution, while the phosphate concentration (0.2 mg/L) indicates a moderate anthropogenic influence, mainly associated with diffuse inputs.

Overall, the study highlights that the Brăila sector of the Danube River exhibits adequate water quality, locally influenced by anthropogenic activities but mitigated by natural transformation processes and the existing wastewater treatment infrastructure.

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