Evaluation of Water Quality in the Danube River at km 181 Area Chiscani Based on the Water Quality Index (WQI)

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Abstract
The Danube River is one of the most significant freshwater resources in Europe, serving a vital role in sustaining natural ecosystems, as well as supporting economic and social activities.
In this study, the overall water quality was assessed on the basis of physico-chemical parameters of the Danube in the area of Chiscani locality at 181 km of the river. The Water Quality Index (WQI) was calculated and according to the obtained values the water quality category of the river section investigated.
The seasonal average values, year 2024, spring, summer, autumn and winter of the essential physico-chemical parameters were analyzed: pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), organic matter, and concentrations of nitrogen compounds such as nitrites (NO_2^-) and nitrates (NO_3^-). The findings indicate a moderate water quality status, with nitrite and nitrate concentrations remaining within permissible limits-suggesting that the influence of agricultural and urban activities is relatively contained. However, the dissolved oxygen levels are at the lower threshold of ecological standards, reflecting a fragile equilibrium within the aquatic environment.
The analysis of the overall water quality of the Danube River in the Chiscani area (km 181) highlights the importance of maintaining a consistent monitoring program, as well as the need to implement, when necessary, proactive measures aimed at protecting aquatic biodiversity and ensuring long-term water quality.

Keywords: aquatic ecosystem, nitrates, nitrites, spectrophotometric methods

1. Introduction

The Danube River, the second longest in Europe, constitutes a complex fluvial ecosystem and a critical freshwater resource for millions of inhabitants within its hydrographic basin. Within the Romanian sector, the Danube holds significant ecological and economic importance, contributing to irrigation networks, hydroelectric power generation, and inland waterway transport [1].

The Chiscani area, situated in close proximity to the municipality of Brăila and adjacent to river kilometer 181, has been historically marked by prolonged and intensive industrial activity.
Among the primary anthropogenic pressures affecting water quality in the region was the Chiscani Pulp and Paper Plant, which was operational from 1959 to 2009 [2].
Throughout its decades of operation, the plant utilized and discharged substantial volumes of industrial wastewater-at times insufficiently treated-into the river. The impact of these discharges on the local aquatic ecosystem, as well as the implications for the quality of raw water used for drinking or agricultural purposes,

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represents a major concern for environmental authorities and the scientific community alike [3].
In 2024, the discharge of the Danube River in the Chiscani area (river kilometer 181) exhibited notable variability, influenced by prevailing hydrological and meteorological conditions. Although site-specific data for this location are limited, available information from nearby monitoring stations provides a general perspective, indicating flow fluctuations that reflect the river's natural dynamics, shaped by factors such as precipitation within the catchment area and snowmelt [3, 4].
To assess the current state of water quality in this area, an effective tool is the Water Quality Index (WQI). This composite indicator integrates multiple physico-chemical parameters into a single synthetic value that is easy to interpret. The calculation of the WQI provides an overview of the degree of pollution and enables comparisons across different locations and monitoring periods [5].
The present study aims to assess the current state of the Danube River's water quality in the area of kilometer 181 – Chiscani, by analyzing relevant chemical parameters and identifying potential traces of historical pollution.
The Water Quality Index (WQI) was determined using recent data on key water quality parameters, including pH, dissolved oxygen, organic matter, calcium, magnesium, chlorides, nitrite and nitrate concentrations, as well as ammonium and ammonia levels. The objective is to classify the area within a standardized water quality class and to identify potential historical or current influences on the aquatic ecosystem.

2. Materials and methods

All water samples from the Danube River were collected from the same sampling station, (1994 and 2024), shown in Figure 1. Water samples were collected under strict hygienic conditions, avoiding contamination. Each sample was analyzed within 24 hours of collection.

Figure 1. The sampling station - Chiscani area Km 181 Danube (Source: google maps)

In order to establish the physico-chemical parameters of the water, water samples were taken twice a month, throughout the years 1994 and 2024, their analysis being carried out in the chemistry laboratory of ICDEAPA Galati, according to Order no. 161 of 16/02/2006 for the approval of the Normative on the classification of surface water quality in order to establish the ecological status of water bodies.
The Water Quality Index (WQI) was used to

assess the level of pollution based on the seasonal average values from the years 1994 and 2024, for a set of 14 representative parameters. The arithmetic weighted mean method was applied,
with the weight of each parameter determined according to the limit values established in the regional water quality standards. The temporal evolution of the WQI was analyzed, and the values for the two reference years—1994 and 2024 - were compared. The year 1994 was selected as a baseline, given that during that period, the Chiscani Pulp and Paper Plant was still operational.
The concentrations of physico-chemical parameters were determined, namely: pH, dissolved oxygen, organic matter, calcium, magnesium, chlorides, nitrite and nitrate concentration, ammonium ions and ammonia, and total hardness. The aforementioned indicators were determined using standard methods: ammonia, nitrite, nitrate and ammonium ions - by spectrometric method using spectrophotometer DR 2800 Hach Lange DR 2800, total hardness, chlorides, CCO-Mn - by titrimetric method [6-12].
The obtained results were compared with water quality standards established by relevant authorities, such as the World Health Organization (WHO) or national legislation. The data were subjected to statistical analysis in order to assess the significance of the findings [13].
For surface waters intended for fish farming, the Water Quality Index (WQI) has been adapted taking into account the parameters relevant for aquatic life, as required by EU directives and national legislation (Ord 161/2006) [14, 15].
For each parameter, a sub-index was calculated to reflect water quality in relation to established standards, with appropriate weights assigned based on the relative importance of each parameter, in order to obtain the final WQI value [16, 17].
For each parameter i:

$$Wi = \frac{K}{Si}$$

where:

- Si is the accepted standard value for parameter i (according to Order 161/2006);
- K is a correction factor determined so that the sum of all weights equals 1, that is.:

$$K = \frac{1}{\sum_{i=1}^{n} \frac{1}{Si}}$$

The relative weight (Wi) was calculated using the formula:

$$WQI = \frac{\sum_{i=1}^{n}(Wi * qi)}{\sum_{i=1}^{n} Wi}$$

where wi indicates the individual parameter weight and
n is the number of groundwater parameters.
The quality rating scale (qi) of each parameter was estimated using Eq:

$$q_i = \left(\frac{Ci - Cideal}{Cideal - Cmin}\right) * 100$$

3. Results and discussion

The monthly and seasonal averages for the 14 identified parameters (Temperature, pH, The organic substance, COD-Mn, Calcium Ca^{2+} , Magnesium Mg^{2+}, Ca^{2+}/Mg^{2+} ratio, Total hardness, Nitrites NO_2^-, Nitrites NO_3^-, Chlorides Cl^-, Ammonium NH_4, Ammonia NH_3 and BOD) the following standard values were established based on Order 161/2006 in Table 1.
The assessment of water quality based on the Water Quality Index (WQI), using the weighted arithmetic mean method [16], allows the classification of water into five categories:

Interval WQI	Water quality
0 – 25	Excellent
26 – 50	Good
51 – 75	Moderate
76 – 100	Unsatisfactory
> 100	Polluted / very bad

It is important to emphasize that there are not many specific published studies related to kilometer 181 of the Danube in the Chiscani area. Consequently, carrying out an own assessment, adapted to local conditions, was essential to obtain relevant results.
An assessment of water quality at kilometer 181 of the Danube River, in the Chiscani area, was carried out in order to identify the presence and concentrations of pollutants using the Water Quality Index (WQI). This composite indicator was employed to synthesize the chemical data into a single value reflecting the overall water quality.

Table 1. Standard values were established based on Order 161/2006

Parameter	Note	Si (din ord 161/2006)*	Unit of measurement
Temperature	T	25	°C
pH	pH	8.5	–
The organic substance	SO	60	mgKMnO4/L
COD-Mn	CCO-Mn	10	mgO2/L
CalciuM Ca2+	Ca	160	mg/L
Magnesium Mg2+	Mg	50	mg/L
Ratio Ca2+/Mg2+	Ca/Mg	5	raport
Total hardness	GH	20	0D
Nitrites NO2	NO_2^-	0.2	mg/L
Nitrites NO3	NO_3^-	5	mg/L
Chlorides Cl-	Cl^-	50	mg/L
Ammonium NH4	NH_4^+	2	mg/L
Ammonia NH3	NH_3	0,2	mg/L
BOD	BOD	7	mg/L

Note: The values presented represent the specific standard values of quality class II (the admissible limits) of Order 161/2006, which vary according to the quality class analyzed. The data obtained for this area were used for the WQI calculation.

The temporal evolution of the seasonal averages of the physico-chemical parameters analyzed for the year 2024, as well as the comparative values from 1994 (used as a historical reference point), is illustrated in Figures 2, 3, 4, and 5.

The pH values generally showed a slightly alkaline reaction, without major oscillations during the studied period, which reflects a relatively constant composition of the values over time.

The water reaction was generally favorable for the survival of aquatic organisms, particullary fish, with values ranging between of 7.87 and 8.88 uph. In comparison, the reference year recorded pH values between 7.28 and 8.29, also within an acceptable range for aquatic life.

The content of the organic substances, expressed in mg $KMnO_4$/l, ranged between 26.79 mg $KMnO_4$/l and 47.65 mg $KMnO_4$/l depending on the water temperature and the intensity of the decomposition processes of dead aquatic organisms.

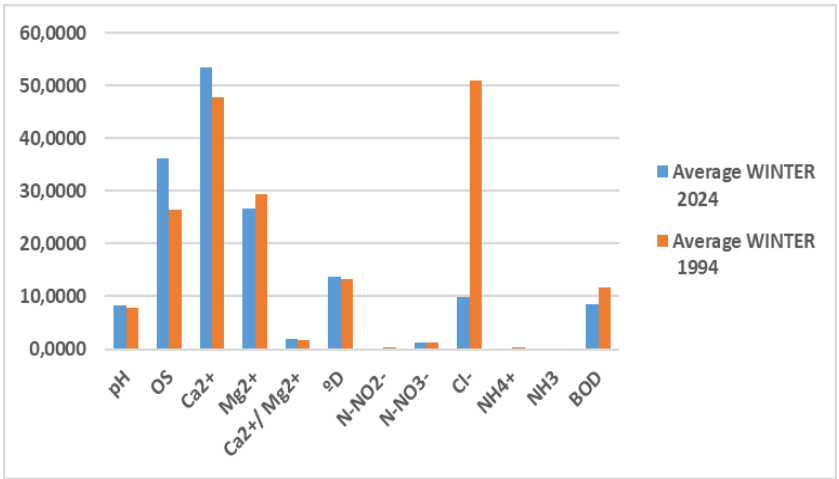

Figure 2. Average values of physico-chemical parameters in winter season Danube river, Km 181 (2024) and control (1994)

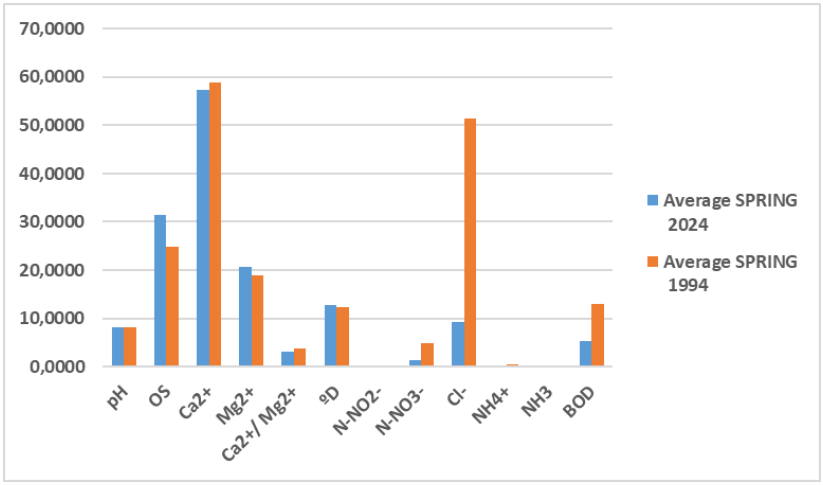

Figure 3. Average values of physico-chemical parameters in spring season Danube river, Km 181 (2024) and control (1994)

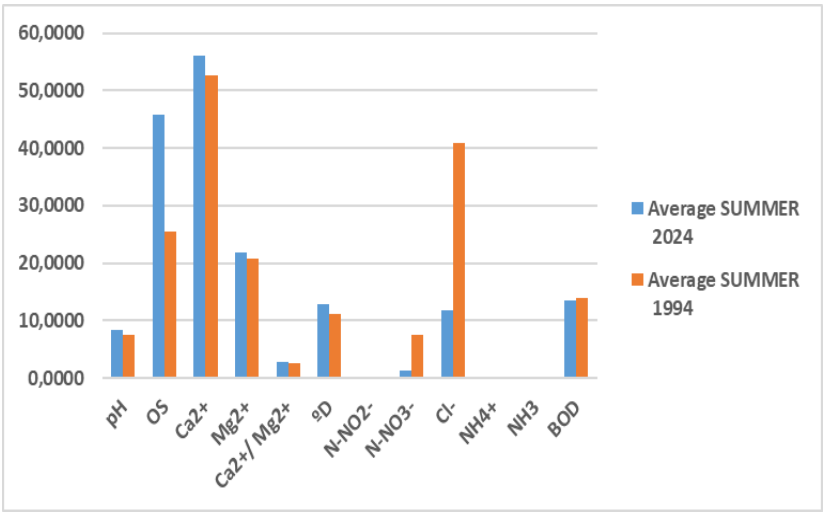

Figure 4. Average values of physico-chemical parameters in the summer season - Danube river, Km 181 (2024) and control (1994)

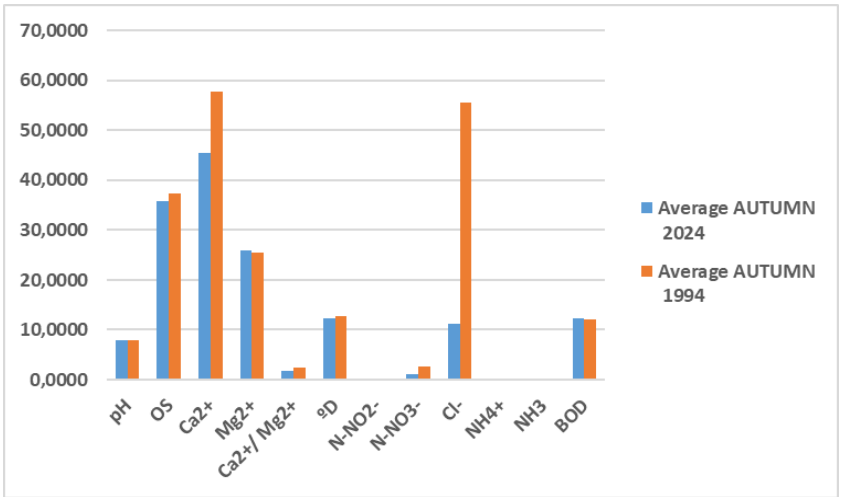

Figure 5. Average values of physico-chemical parameters in the fall season Danube River, Km 181 (2024) and control (1994)

The highest levels of organic matter was recorded the summer season, in July and autumn, in October, while the lowest were observed in spring in March. By comparison, the reference year exhibited values ranging from 18.02 to 52.88 mg $KMnO_4$/l.

Elevated levels of organic substances indicate the presence of a consistent source of organic matter, likely resulting from the decomposition of aquatic organisms, both flora and fauna.

Calcium content in water, expressed in mg/l, is a key component of aquatic ecosystems, playing a vital role in the growth, development, and metabolic functions of aquatic organisms, particularly in supporting fish nutrition.

The calcium concentrations showed notable differences, with values ranging from 40.08 mg/l in November (autumn) to a peak of 60.12 mg/l observed in February (winter) and August (summer). In comparison, the control values fell within the range of 35.52 to 75.48 mg/l.

Magnesium in water, expressed in mg/L, is an essential element for the development of fish organisms. Its concentrations ranged from 12.39 mg/l in March (spring) to a peak of 30.13 mg/l in June (summer). In comparison, the reference values were within the range of 10.65 to 56.93 mg/l.

The calcium-to-magnesium ion ratio, a dimensionless parameter, is ideally around 5:1 in productive waters. During the year 2024, the recorded values ranged from a minimum of 1.65 in November (autumn) to a maximum of 4.66 in March (spring). In all cases during the studied period of 2024, the ratio was greater than 1, indicating a consistently higher concentration of calcium compared to magnesium in the water. These two cations play a key role in determining water hardness, with calcium being the predominant contributor in this case. The reference values from 1994 ranged between 1.08 and 5.84.

During the studied period of 2024, the ratio of calcium and magnesium cations is in all cases above unity, which proves the existence of a greater amount of calcium in the water compared to magnesium, these cations being the ones that will predominantly determine hardness.

The water hardness, expressed in German degrees (°D), remained in all analyzed cases below the maximum allowable concentration established by the current legislation for second-category surface waters, namely 20 °D.

Nitrites, expressed in mg/l, recorded a minimum value of 0.011 mg/L in November (autumn) and a maximum value of 0.024 mg/l in June (summer) during the study period. In comparison, the reference year (1994) showed concentrations ranging between 0.099 and 0.33 mg/l. The nitrite concentrations measured at kilometer 181 of the Danube River, in the Chiscani area, remained well below the maximum permissible limit established by current legislation, which is 0.2 mg/l.

Nitrates, expressed in mg/l, showed a minimum value of 0.774 mg/l in winter, in November, and a maximum value of 1.88 mg/l in February. Both the nitrogen concentrations determined in the year 2024 and in the control 1994 had low values compared to the maximum concentration allowed by the current legislation, respectively 3 mg/l.

Chlorides, expressed in mg/l, recorded minimum concentrations of 6.38 mg/l in June (summer) and maximum values of 12.77 mg/l in August. Compared to the reference year 1994, when values ranged between 30.0 and 71.7 mg/l, all measurements remained well below the maximum allowable concentration established by current legislation, namely 3 mg/l.

Ammonium, in mg/l, showed a minimum value of 0.024 mg/l in spring, in March and a maximum value of 0.17 mg/l in June, in summer.

Ammonium concentrations determined in the year 2024 as well as in the control year 2019 had low values compared to the maximum admitted concentration of 2 mg/l.

Ammonia, in mg/l, showed a minimum value of 0.002 mg/l in December in winter and a maximum value of 0.011 mg/l in June in summer, compared to the control, with values in the range 0.001-0.04 mg/l.

The standard values for Class II surface water quality, as established by Order 161/2006 (Romania), were used to determine the Water Quality Index (WQI) for the Danube River at kilometer 181, in the Chiscani area.

Input data - Measured values and standards for class II Table 2.

The final WQI value, representing the annual average for 2024, was 64.22, indicating a moderate water quality according to standard WQI classification (Figure 6). In comparison, the WQI recorded in 1994 was 67.2.

Table 2. Measured values and standards for class II

Parameter	Measured value	Class II Standard	Ideal value V_{ideal}	Remarks
pH	8.14	8.5	7	
Organic substance*	36.53	-	-	Not included directly in WQI
Calcium(Ca^{2+})	53.21	-	-	Not included directly in WQI
Magnesium (Mg^{2+})	25.09	-	-	-
Ca^{2+}/Mg^{2+}	2.26	-	-	Report, not used
Duritate totală	13.25	-	-	Can be excluded
NO_2^- (Nitrites)	0.02 mg/L	0.03 mg/L	0	
NO_3^- (Nitrates)	1.19 mg/L	3 mg/L	0	
Cl^- (Chlorides)	10.28 mg/L	25 mg/L	0	
NH_4^+ (Ammonium)	0.09 mg/L	0.4 mg/L	0	
NH_3 (Ammonia)	0.01 mg/L	0.025 mg/L	0	
BOD	4.18 mg/L	5 mg/L	0	

*Organic substance, calcium, magnesium, hardness and Ca/Mg ratio are not normally included in the classical WQI (arithmetic method).

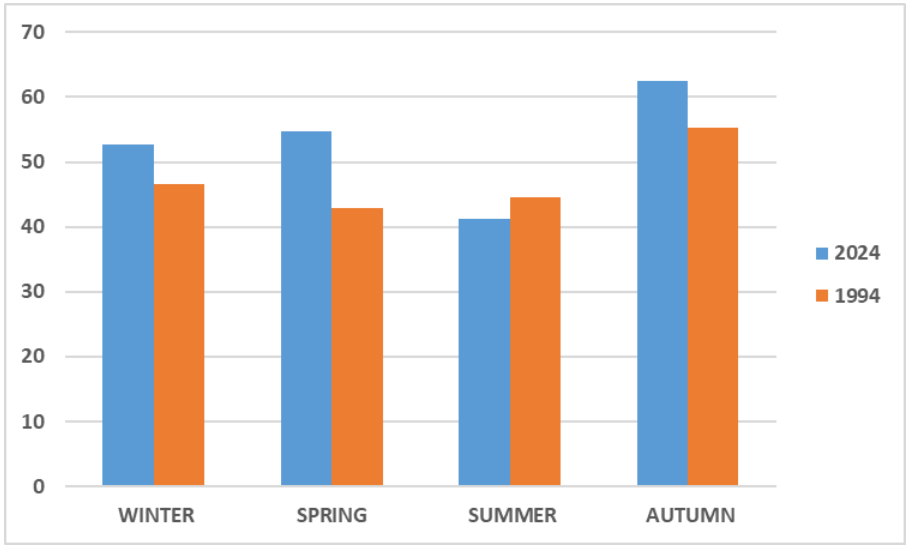

Figure 6. Average WQI variation

4. Conclusions

The analysis of the temporal evolution of water quality parameters in the Danube River, particularly at kilometer 181 near the locality of Chiscani, is of great importance for both researchers and authorities. It provides valuable insights into long-term changes occurring within this hydrological basin. By monitoring these parameters, the effectiveness of pollution control measures implemented in the area can be assessed, thus contributing to the fulfillment of national and international environmental protection commitments. This analysis also helps to better understand the impact of human activities on water quality and supports the development of more effective strategies for the conservation of water resources.

The interpretation of the results was carried out in accordance with the provisions of the Normative on the classification of surface water quality in order to determine the ecological status of water bodies (MMGA Order no. 161/2006) and correlated with the data from the literature for surface waters (waters used for fish farming). The water quality of the Danube at km 181 indicates a moderate status, highlighting the need for pollution reduction measures to improve ecosystem conditions According to Order

161/2006 most of the parameters fall into Class I quality standards.

Parameters significantly improved (2024 vs. 1994):

- Nitrates (NO_2^-) and nitrites (NO_3^-) are in Class II, but with significantly better values than in 1994.
- Nitrates (NO_2^-): decrease from 0.33 to 0.032 mg/L→indicates reduction of recent pollution.
- Nitrates (NO_3^-): from 16.96 to 1.88 mg/L→less background pollution (nitrates).
- Chlorides (Cl^-): massive decrease → possible elimination of an industrial or agricultural source.
- Ammonium and ammonia: consistent reductions→much cleaner water biologically.

Relatively constant parameters:

- Hardness, Ca, Mg, Ca/Mg ratio - small variations, normal for the Danube area.
- BOD: from 14.6 to 12.6→insignificant variations in organic pollution.

Parameters with increased values:

- Organic matter slightly increased→may be influenced by vegetation or natural processes, but no major negative impact.

Characterization of Danube water quality in the Chiscani area (km 181)

The analysis of the physico-chemical parameters sampled from the Danube in the Chiscani area (km 181) led to the calculation of a Water Quality Index (WQI) of 64.22, a value indicating a moderate water quality according to international assessment standards. This value places the water in the second quality class according to Order no. 161/2006 on the classification of surface water quality in Romania.

Parameters that significantly influenced the WQI value include:

- a moderate level of biochemical oxygen consumption (BOD=4.18 mg/l), which signals the presence of biodegradable organics; dissolved oxygen is at the lower limit of optimum values for aquatic life and BOD level indicates moderate organic loading.
- a detectable concentration of nitrogen compounds. (NO_2^-, NO_3^-, NH_4^+, NH_3), suggesting nutrient inputs, most likely from anthropogenic sources (wastewater, agricultural activities);a slightly alkaline pH (8.14upH), typical of waters with intense biological activity and potentially influenced by photosynthetic processes or alkaline discharges.

In the analyzed area (Chiscani, km 181) there is a certain improvement in the quality of the Danube water in the last 30 years.

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Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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