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LJILJANA TAKIĆ[1]
IVANA MLADENOVIĆ-RANISAVLJEVIĆ[2]
VIOLETA STEFANOVIĆ[3]

[1,2]University of Niš, Faculty of Technology, Serbia
[3]Inspection Department, City Administration of Leskovac, Serbia

[1]ljilja_t@yahoo.com
[2]ivanamladenovic@tf.ni.ac.rs
[3]violetastefanovic.le@gmail.com

ENVIRONMENTAL PROTECTION BY PRESERVING THE REQUIRED QUALITY OF SURFACE WATER

Abstract: *The paper provides an assessment of the water quality of the Danube River at the measuring station of Novi Sad as a function of oxygen consumption indicators in surface waters (BOD_5 and NH_4–N). The aim is to achieve the principle of sustainable water management of the Water Framework Directive (WFD). For surface waters, the main goal of the WFD is to achieve "good status", i.e., class II of ecological status of water quality, which shows a low level of changes in the ambient state of the environment. The calculated values of environmental protection indicators (BOD_5 =2.6 mg/l and NH_4–N =0.08 mg/l) at the observed measuring station place the water quality of the Danube into the required class II of the ecological status. The ecosystem approach indicates that the concentrations of the observed parameters BOD_5 and NH_4–N correspond to the target values of the required water quality of the Danube as an integral part of the environment.*

Keywords: environment, indicators of oxygen consumption, the Danube

ORCID iDs: Ljiljana Takić https://orcid.org/0000-0002-0462-836X
Ivana Mladenović-Ranisavljević https://orcid.org/0000-0002-3112-428X
Violeta Stefanović https://orcid.org/0000-0002-0444-6523

INTRODUCTION

Anthropogenic sources of river pollution can significantly affect the composition of river waters and sediments (Kašanin-Grubin et al., 2023). In economic and population terms, the most developed part of the Republic of Serbia is along the banks of the Danube, where the dominant polluters from industry are registered (Takić et al., 2012). The measuring station at Novi Sad was observed - an industrial centre where the refinery, chemical industry, and food industry are inflexibly located - which contributes significantly to the pollution of the Danube by the quantity and concentration of hazardous substances. By monitoring and preserving the required quality of the Danube water, continuous control of the state of the environment is ensured.

Water protection is considered to be the most comprehensively regulated area within the legislation of the European Union in the field of environmental protection. The European Union determined its long-term policy in the domain of water by adopting the Water Framework Directive (WFD). The WFD is the most important legal instrument in the field of water and a prerequisite for the successful realization of the concept of integral management of the environment. The Directive has formulated certain conditions that should enable the implementation of the adopted policy of sustainable use and protection of water. It should be emphasized that the WFD mandates the following goals: comprehensive protection of all waters, achievement of good water quality within 15 years, integral management of the river basin, combined approach regarding standards for limit values of permitted emissions and immissions, proper pricing and public involvement. For surface waters, the general goal of the WFD is to achieve "good status", i.e. class II ecological status of water quality, i.e. low level of natural changes that occur as a result of human activities (EC, 2000).

Surface water bodies such as rivers, lakes, and reservoirs play a vital role in maintaining ecological balance, supporting biodiversity, and providing essential resources for human activities, including drinking water supply, agriculture, industry, and recreation (UNESCO, 2021). However, increasing anthropogenic pressures − such as urbanization, industrial discharge, and agricultural runoff − pose a significant threat to water quality and to the resilience of aquatic ecosystems (EEA, 2020). In this context, continuous monitoring of water quality is crucial to ensuring that environmental standards are met and that water resources are preserved for future generations.

The Danube River, Europe's second-longest river and a crucial international waterway, flows through 19 countries and serves as a vital resource for over 80 million people. Its transboundary nature requires coordinated environmental policies and sustainable management efforts across national borders (ICPDR,

2021). In light of these challenges, the implementation of the WFD across Danube countries has provided a unified framework for monitoring, reporting, and improving water quality. Nevertheless, as highlighted by Hering et al. (2010), significant challenges remain in translating legal obligations into effective ecological outcomes, particularly in regions exposed to persistent pollution sources.

This paper evaluates the surface water quality of the Danube River at the measuring station in Novi Sad, Serbia, by analyzing two key indicators of organic pollution and oxygen consumption: biochemical oxygen demand over five days (BOD_5) and ammonium nitrogen (NH_4–N). These parameters are widely accepted in environmental monitoring as indicators of the degree of organic matter decomposition and the level of nutrient pollution, both of which affect the oxygen regime and ecological health of the water body (Chapman, 1996; Wetzel, 2001).

The main objective of this research is to determine whether the measured values of BOD_5 and NH_4–N are within the thresholds defined for Class II ecological status according to the WFD. Achieving and maintaining this water quality status is not only a legal obligation under the EU framework but also a key measure for environmental protection, public health, and regional sustainability. Through this case study, the paper highlights the importance of aligning local water management practices with European environmental policies, contributing to the broader goal of integrated river basin management and sustainable development.

METHODOLOGY

The paper analyzes selected surface water quality parameters, specifically oxygen consumption indicators BOD_5 and NH_4–N, which are defined as environmental status indicators according to the Rulebook on the National List of Environmental Protection Indicators (Rulebook, 2011).

BOD_5 represents the amount of dissolved oxygen required by microorganisms to biologically decompose organic matter in water over five days. It is a fundamental indicator of organic pollution in surface waters, as the required oxygen quantity is proportional to the amount of biodegradable organic substances present. Elevated organic pollution leads to increased microbial activity and oxygen consumption, which can result in oxygen depletion and anaerobic conditions. Under anaerobic conditions, nitrogen compounds are transformed into reduced forms, leading to increased concentrations of ammonium (NH_4–N), which is toxic to aquatic organisms above permissible limits.

Ammonium (NH_4–N) is formed as a result of the decomposition of nitrogen-containing organic matter. Its presence in surface waters is typically linked to domestic and industrial wastewater discharge, especially from untreated or poorly treated sewage. Elevated concentrations of ammonium can lead to toxic effects on aquatic fauna, particularly fish, depending on environmental conditions such as pH, water temperature, and salinity. Ammonium serves as an indicator of potential bacterial activity often associated with human and animal waste discharge into surface waters (Rulebook, 2011).

For this study, data were obtained from the publicly available annual reports on water quality published by the Serbian Environmental Protection Agency (SEPA, 2024). These reports contain systematic monitoring results of water quality parameters at the measuring station Novi Sad on the Danube River. The data cover monthly measurements during the year and are collected according to national standards harmonized with the Water Framework Directive (EC, 2000).

The analysis focuses on the values of BOD_5 and NH_4–N from the report, examining their compliance with the criteria for Class II ecological status as defined by national legislation and the WFD. The use of official monitoring data ensures the reliability of the results and allows for the evaluation of temporal trends in water quality parameters.

The research was conducted at the hydrological measuring station in Novi Sad, located on the Danube River. This site was selected due to its exposure to significant urban and industrial impacts. Namely, the measuring station at Novi Sad is strategically situated downstream of several significant industrial and urban centers. This includes refineries, chemical plants, and food processing industries, all of which contribute to the potential pollution load of the river. Moreover, the area is influenced by municipal wastewater discharges and agricultural runoff from surrounding lands (Takić et al., 2012; ICPDR, 2021).

Due to its economic importance and the intensity of anthropogenic activities along its banks, the Danube section near Novi Sad represents a critical point for water quality monitoring and environmental assessment. Continuous surveillance of water quality at this station provides valuable data that reflects both local pollution pressures and broader environmental trends in the Danube basin (EEA, 2020).

The hydrological characteristics of the Danube at Novi Sad, such as flow regime, temperature fluctuations, and seasonal variations, also play a role in shaping the water quality parameters analyzed in this study. Understanding the specific conditions of this area is essential for interpreting monitoring results and implementing effective water management strategies (ICPDR, 2021).

RESULTS AND DISCUSSION

The most recent published results of surface water monitoring provided by the Serbian Environmental Protection Agency for 2023 (SEPA, 2024), along with valid national legislation in the field of water, were used. The ecological classification of Danube water is determined in accordance with the methodology prescribed by the Regulation on emission limit values of polluting substances in surface and groundwater and deadlines for their achievement (Regulation, 2012)

which includes legislation in Serbia harmonized with the requirements of the WFD. The Danube belongs to Type 1 of large rivers with the dominance of fine sediment, for which the target concentrations of parameters for the corresponding classes of the ecological status of the water are defined by the current regulations (Table 1).

Table 1. *Limit values of oxygen consumption parameters (Type 1)*

Parameter	Class I	Class II	Class III	Class IV	Class V
BOD_5 (mg O_2/l)	2	5	7	52	>25
NH_4–N (mg/l)	0.1	0.1	0.6	1.5	>1.5

The calculated mean annual values of environmental protection indicators BOD_5 and NH_4–N place the water quality of the Danube at the observed measuring station into class II and I, respectively (Table 2). In summary, the water quality of the Danube at the measuring station Novi Sad corresponds to the required class II ecological status according to national regulations harmonized with the Water Framework Directive (EC, 2000).

Table 2. *Calculated values of oxygen consumption parameters and classification*

Parameter	Novi Sad	Class
BOD_5 (mg O_2/l)	2.6	II
NH_4–N (mg/l)	0.08	I

The concentrations of the observed parameters BOD_5 and NH_4–N correspond to the prescribed limit (target) values for Class II surface water quality. This class implies a low level of deviation from natural conditions, meaning that the anthropogenic impact is present but limited and does not significantly disturb the structure and function of aquatic ecosystems (EEA, 2020; Rulebook, 2011). The limit value of the required Class II represents the environmental quality standard expressed as a threshold concentration of pollutants in surface waters. These standards are set to protect aquatic life, maintain ecological integrity, and ensure safe usage of water for multiple purposes, including recreation and irrigation (ICPDR, 2021).

BOD_5, as an indicator of organic pollution and microbial oxygen demand, reflects the presence of biodegradable matter in water. The mean value observed at Novi Sad was below the 5 mg/l threshold set for Class II, which confirms a moderate level of organic load and sufficient oxygen availability for aquatic organisms (Chapman, 1996). This suggests that the self-purification capacity of the river is preserved, and that input from urban and industrial effluents is either properly treated or sufficiently diluted by river flow.

NH_4–N, which signals potential contamination by sewage or agricultural runoff, was well within the Class I limit (< 0.1 mg/l), indicating that ammonium levels are minimal and do not pose acute toxicity risks to aquatic fauna. This is particularly important because elevated ammonium concentrations can impair fish respiration and disrupt nitrogen cycling in aquatic ecosystems (Wetzel, 2001). The low NH_4–N value also implies that the wastewater treatment infrastructure upstream may be functioning effectively or that dilution conditions are favorable.

The fact that both parameters remain within acceptable limits across the observed period highlights a degree of stability and resilience in the Danube's aquatic system at Novi Sad. Class II ecological status, as defined by the Rulebook (2011), indicates that the vitality of the ecosystem has not been impaired, ensuring the preservation of the structure and functioning of the Danube's aquatic environment. Although BOD_5 places the water in Class II and NH_4–N in Class I, the final classification is determined by the worst parameter, in line with the “one out, all out” principle of the WFD (Hering et al., 2010). Therefore, the overall status remains at Class II, which still satisfies the "good status" criterion of the Directive.

However, it is important to note that this classification represents an average condition and does not exclude the possibility of temporal fluctuations or localized pollution events. Occasional peaks, especially during low-flow periods or after industrial discharges, could temporarily deteriorate water quality. Hence, continuous monitoring and improvement of wastewater management remain essential for the long-term protection of the Danube and the achievement of higher ecological status in the future.

The second class of ecological status of water quality (Class II) shows that the vitality of the ecosystem has not been impaired, thus preserving the quality of the structure and functioning of the Danube's aquatic system as an integral part of the environment.

CONCLUSION

The conducted analysis of selected environmental protection indicators BOD_5 and NH_4–N demonstrates that the Danube River at the measuring station in Novi Sad meets the criteria for Class II ecological status. While NH_4–N concentrations consistently fall within the Class I range, the slightly elevated BOD_5 values limit the overall classification, following the precautionary “one out, all out” approach mandated by the Water Framework Directive. This classification confirms that the water quality reflects a low degree of anthropogenic influence, with preserved ecological functionality and biological integrity.

This result is encouraging in the context of the Danube’s strategic importance for Serbia – as a source of drinking water, irrigation, industrial usage, recreation, and ecological balance. The Novi Sad region, as an urban and industrial hub, represents a

critical pressure point for river water quality, and the observed status reflects the combined effects of existing wastewater treatment practices, natural self-purification potential, and hydrological conditions.

The application of national legislation, particularly the Regulation on Emission Limit Values of Polluting Substances in Surface and Groundwater (Regulation, 2012), provided a robust legal framework for assessment. The classification by river type (Type 1 large lowland river with fine sediment) ensures that the ecological evaluation accounts for natural variability and specific environmental characteristics. The consistency of NH_4–N values with Class I norms points to satisfactory management of sanitary and agricultural sources of pollution, while BOD_5 remains an indicator that requires continued attention due to the complexity of its sources, which often include both point and diffuse inputs.

Despite the overall positive ecological status, it is important to emphasize that Class II represents a "good" condition but not a fully pristine one. The potential for temporary deterioration due to accidental discharges, hydromorphological alterations, or seasonal stress (e.g., low flow periods, and high temperatures) must be carefully managed. Regular and integrated water quality monitoring is therefore essential, along with targeted interventions in sectors with high pollutant loads.

In the broader context of the Danube River Basin, which spans 19 countries, this study underscores the value of transboundary water cooperation and harmonized data collection. Achieving and maintaining good ecological status requires alignment between local, national, and international efforts. Serbia's progress in implementing WFD principles contributes to the shared responsibility for protecting one of Europe's most vital river systems.

Future research should expand the analysis to include biological indicators (such as macroinvertebrates or phytoplankton), hydromorphological parameters, and emerging pollutants (e.g. microplastics, pharmaceuticals), which are increasingly relevant in ecological assessments. Moreover, coupling chemical data with ecological risk assessments and modeling of pollution sources could provide a more comprehensive understanding of river health and support evidence-based policy decisions.

Ultimately, safeguarding the required quality of the Danube's surface water is not merely a regulatory task - it is a strategic imperative for sustainable development, environmental protection, and the well-being of current and future generations across the Danube basin.

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