Acta et Commentationes, Exact and Natural Sciences
Volume 21(1), 2026, Pages 166–173
UDC: 502/504+574(478)

DOI: 10.36120/2587-3644.v21i1.166-173
ISSN: 2537-6284 E-ISSN: 2587-3644

The eutrophication process of lakes within the Emerald site "Vila Nisporeni"

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Abstract. Water pollution is an imperative of the current times, which disrupts the drinking water supply as well as the natural processes in aquatic basins. Eutrophication, representing one of these processes, which has a direct impact on the biodiversity and functioning of aquatic ecosystems, especially lakes. Thus, the present study analyzes the eutrophication process of lakes from the Emerald site "Vila Nisporeni", located in the center of the Republic of Moldova, by evaluating nutrient concentrations (total mineral nitrogen) and trophic state indicators (chlorophyll "α" and transparency) relevant for assessing the ecological state of the lakes. The results indicate a moderate to advanced level of eutrophication, mainly driven by excessive nutrient inputs originating from surface runoff, agricultural activities, and land use in adjacent areas. The waters in the lakes of the Emerald "Vila Nisporeni" site correspond to the eutrophic and hypereutrophic trophic state, and some lakes are subject to the clogging process.
Keywords: eutrophication, chlorophyll "a", transparency, TSI, lakes.

Procesul de eutrofizare a lacurilor din site-ul Emerald „Vila Nisporeni"

Rezumat. Poluarea apelor este un imperativ al timpurilor actuale, ce perturbă alimentarea cu apă potabilă cât și procesele naturale din bazinele acvatice. Eutrofizarea, reprezentând unul din aceste procese, ce are impact direct asupra biodiversității și funcționării ecosistemelor acvatice, în special al lacurilor. Astfel prezentul studiu analizează procesul de eutrofizare a lacurilor din site-ul Emerald „Vila Nisporeni", situat în centrul Republicii Moldova, prin evaluarea concentrațiilor nutrienților (azot mineral total) și indicatorii stării trofice (clorofila „α" și transparența) relevanți pentru aprecierea stării ecologice a lacurilor. Rezultatele obținute indică un nivel moderat spre avansat de eutrofizare, determinat în principal de aportul excesiv de nutrienți proveniți din scurgerile de suprafață, activitățile agricole și utilizarea terenurilor din zona adiacentă. Apele din lacurile site-ului Emerald „Vila Nisporeni" corespund stării trofice eutrofice și hipereutrofice, iar unele lacuri sunt supuse procesului de colmatare.
Cuvinte-cheie: eutrofizare, clorofila „a", transparența, TSI, lacuri.

1. Introduction

Lakes play a fundamental role in preserving biodiversity and providing basic ecosystem services, as well as in maintaining ecological balance. These ecosystems are currently subject to increased anthropogenic pressures. The result of these pressures are nutrients, especially nitrogen and phosphorus compounds, which trigger the eutrophication process of lakes and slow-flowing rivers, representing one of the most frequent and severe forms of water quality degradation. Thus, the increased nutrient content creates favorable conditions for the excessive development of algal biomass, reducing water transparency, and modifying the dissolved oxygen regime, affecting the structure and functioning of biological communities.

The study included the lakes from the Emerald site "Vila Nisporeni", given that they are part of an integrated environmental study of the Emerald sites in the Republic of Moldova, which are created, in accordance with the Bern Convention, for the conservation of biodiversity exposed to the action of the anthropogenic factor [3]. These lakes are exposed to the eutrophication process, as a result of the interaction between natural factors and anthropogenic activities, especially agricultural works.

The factors that load aquatic ecosystems with nutrients are: surface runoff, intensive agricultural practices, unmonitored use of fertilizers and changes in land use, etc. These conditions are favorable factors for the development of invasive aquatic plants and algae, as well as phytoplankton and macroalgae, being also accompanied by the proliferation of cyanobacteria. Depending on the degree of eutrophication, severe environmental effects may develop, which degrade water quality. For example, the growth of phytoplankton biomass may decrease water clarity, reduce light levels and decrease oxygen levels, all of which ultimately have negative consequences for organisms living in the lake.

In the context of all the factors that participate in the eutrophication process and the phenomena that arise from their cumulative action, the eutrophication process of natural and artificial biotopes is considered a result of the increase in the amount of chemical substances generating primary production in the biotope, under conditions of a thermal regime and water circulation favorable to the phenomenon [8], [12].

The Emerald site "Vila Nisporeni", located in the center of the Republic of Moldova, includes lakes of high ecological importance, which provide habitats for numerous species of aquatic and semi-aquatic flora and fauna. At the same time, these lakes are subject to anthropogenic impact, especially runoff from agricultural lands.

In the absence of adequate nutrient and watershed management, eutrophication may compromise the ecological status of the lakes and the conservation objectives established for the Emerald site.

In this context, the present study aims to analyze the eutrophication process of the lakes in the Emerald site "Vila Nisporeni", by evaluating nutrient concentrations (total mineral nitrogen) and trophic status indicators, such as chlorophyll "a" and water transparency. The results obtained contribute to the characterization of the ecological status of the lakes and provide scientific support for the development of management and protection measures for aquatic ecosystems within the Emerald sites.

2. Materials and methods

To assess the eutrophication process of the lakes within the Emerald site "Vila Nisporeni", surface water samples were collected in accordance with national standards [10].

Methods for physico-chemical parameter analysis: Water samples were analyzed for quality indicators in compliance with national standards regarding processing methods and determination of physico-chemical parameters, including: pH, COD-Cr (chemical oxygen demand — dichromate method), total inorganic nitrogen (nitrates, nitrites, ammonium), chlorophyll a, and water transparency [1].

Statistical and mathematical methods used for data processing and interpretation:

Statistical processing of the obtained data primarily involved the calculation of statistical parameters such as arithmetic mean, standard error of the mean, and 95% confidence level, using the Descriptive Statistics application in Microsoft Excel. Correlation analysis is independent of the unit of measurement and is applied only to normally distributed values. The strength of correlation was interpreted as follows: [0–0.2] → very weak correlation [0.2–0.4] → moderate correlation, [0.4–0.6] → good correlation, [0.6–0.8] → high correlation, [0.8–1] → very high correlation → very strong relationship between variables or possible calculation error of R^2 (correlation coefficient) and the coefficient of determination r^2 [4], [11].

The Trophic State Index (TSI) evaluates the eutrophication level based on Secchi depth transparency (SD, in meters), chlorophyll a concentration (ChL, in μg/L), total phosphorus concentration (TP, in μg/L), and total mineral nitrogen (mg/L) [6], [9].

Calculation and correlation equations:

$$TSI = 60 - 14.4 \ln(SD) \tag{1}$$

$$TSI = 9.81 \ln(ChL) + 30.6 \tag{2}$$

$$TSI = 14.42 \ln(TP) + 4.15 \tag{3}$$

The index values were estimated according to Table 1:

Table 1. Interpretation of trophic status index values, according to (LEE şi LIN 2007)

Trophic status	**Transparency (m)**	**Chlorophyll a (μg/L)**	**Total phosphorus (μg/L)**	**TSI**
Oligotrophic	> 4	< 2.6	< 12	< 40
Mesotrophic	2–4	2.6–7.2	12–24	40–50
Eutrophic	0.5–2	7.2–55.5	24–96	50–70
Hypereutrophic	< 0.5	> 55.5	> 96	> 70

The trophic status of water can also be determined in accordance with the Hygienic Regulation "Protection of Water Bodies Against Pollution" (Sireţeanu et al., 1997) [9], which was subsequently amended by the provisions of Order no. 161/2006 of the Romanian Ministry of Environment and Water Management [7] approving the Normative on the Classification of Surface Water Quality for the purpose of establishing the ecological status of water bodies.

This approach is applied because such information is lacking in the national regulation, while the eutrophication process occurs in many lakes and small rivers within the Republic of Moldova.

3. Results and discussion

The collected samples were collected from the Emerald site "Vila Nisporeni" and adjacent areas: during the spring season (2 lakes) and during the summer–autumn period (4 lakes).

The eutrophication status of the lakes was assessed using both the conventional classification and the classification based on Carlson's Trophic State Index (TSI).

Anthropogenic eutrophication processes in aquatic ecosystems represent significant environmental issues of our time. The trophic status of a lake ecosystem is the result of complex interactions among processes occurring under the influence of natural and anthropogenic factors, not only within the water body itself but also across the entire watershed. Natural factors include lake surface area, depth, bottom morphology, water circulation, temperature, and the replenishment of water balance deficits through precipitation, groundwater, and small tributary streams. Anthropogenic factors include agricultural fields, farms, and streams discharging polluted waters, among others.

Thus, the increase in nutrient and organic matter content becomes a major threat, particularly for small reservoirs whose self-purification capacity is significantly reduced, leading to eutrophication through the stimulation of excessive algal growth.

The ecological potential of the lakes within the study area, according to the trophic index, was evaluated by determining water transparency (Secchi disk depth), chlorophyll a concentration, total mineral nitrogen, and COD-Cr.

Based on these parameters, $\mathbf{TSI_{Chl}}$, $\mathbf{TSI_{SD}}$, $\mathbf{TSI_{tot}}$ were estimated, along with the trophic status [5], [6], [7], [9]. Lakes no. 3 and no. 4 exhibited eutrophic characteristics (Table 2) during both spring and summer. Lakes no. 1 and no. 2 corresponded to a hypereutrophic state during the summer period. In autumn, the condition of Lake no. 3 improved toward a eutrophic status due to abundant rainfall, which diluted nutrient concentrations. In contrast, Lake no. 4 showed advanced siltation by autumn, and even heavy rainfall could not halt this process.

Table 2. Values of the trophic status index of the water of the lakes in the study area

Spring					
Nr.	**Sample**	$\mathbf{TSI_{Chl}}$	$\mathbf{TSI_{SD}}$	$\mathbf{TSI_{tot}}$	**Trophic status**
3.	Lake near cantonment no. 4.	59	50	54.5	Eutrophic
4.	Lake, near the nursery	66	49	58	Eutrophic
Summer					
1.	Lake at the exit of Bujor village.	75	77	76	Hypereutrophic
2.	Private lake, bordering area	71	70	70.5	Hypereutrophic
3.	Lake near cantonment no. 4.	66.4	49	58	Eutrophic
4.	Lake, near the nursery	65	49	57	Eutrophic
Autumn					
1.	Lake at the exit of Bujor village.	83	86	84.5	Hypereutrophic
2.	Private lake, bordering area	67	70	68.5	Eutrophic
3.	Lake near cantonment no. 4.	66	50	58	Eutrophic
4.	Lake, near the nursery	SIL	T	E	D

The trophic status of the studied lakes is also confirmed by the COD-Cr values. Chemical oxygen demand determined by the potassium permanganate or potassium dichromate method represents the concentration of reducing substances, predominantly dissolved organic matter in water [8].

Low concentrations of dissolved organic substances, below 10 mg O_2/L, do not generally lead to significant increases in phytoplankton production within the biotope, nor to the onset of eutrophication. Dissolved organic matter is considered the energy substrate supporting planktonic and bacterial production, while also being a byproduct of primary production.

Higher concentrations of dissolved organic substances, approximately 15–20 mg O_2/L, may initiate the eutrophication process and can progressively increase to COD values exceeding 40–50 mg O_2/L [8]. This is consistent with the trophic status identified in the studied lakes. Dissolved organic matter, together with biogenic elements such as N–P–Ca, represents a key factor in triggering eutrophication.

This statement is supported by the strong correlation observed between COD-Cr and TSI_{tot} in the studied waters ($R^2 = 0.8063$) (Figure 1). An R^2 value of 0.8063 indicates a strong correlation between TSI_{tot} and COD-Cr; approximately 81% of the variation in COD-Cr is explained by TSI_{tot}. The coefficient of determination r^2 is 0.65, meaning that 65% of the variation in TSI_{tot} values can be explained by changes in COD-Cr, while 35% corresponds to other factors influencing TSI_{tot} that were not included in the calculation (phosphates, temperature, organic nitrogen, etc.).

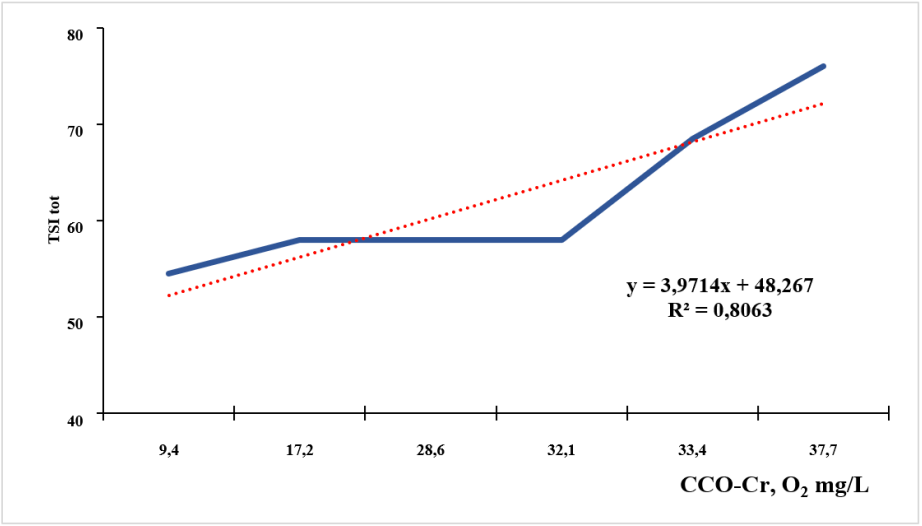

Figure 1. Correlation between TSI_{tot} and COD-Cr in the studied lakes

As a result, it can be concluded that COD-Cr may be used as an indicator of the trophic status of an aquatic ecosystem ($R^2 = 0.8063$).

In order to prevent and control the eutrophication process and its negative effects on lake waters, several measures should be implemented, such as:

- Reducing nutrient inputs through the use of controlled-release fertilizers;
- Applying fertilizers according to the specific needs of crops;
- Establishing buffer zones between agricultural lands and lakes, as well as ensuring their monitoring;

- Ensuring compliance with the European Union Nitrates Directive (91/676/EEC) [2];
- Raising public awareness and education regarding the causes and effects of eutrophication, etc.

The sustainable management of lake eutrophication processes is essential for maintaining ecological balance and ensuring a sustainable environment.

4. Conclusions

COD-Cr can be used as an indicator of the trophic status of aquatic ecosystems.

The waters of the analyzed lakes within the Emerald site ”Vila Nisporeni” correspond to eutrophic and hypereutrophic trophic states and are undergoing a natural siltation process.

The eutrophication process and its negative effects on lake waters can be prevented and controlled by applying measures aimed at reducing nutrient inputs, complying with the EU Directive (91/676/EEC), establishing buffer zones between lakes and agricultural fields, and increasing public awareness.

Acknowledgements. *The data presented in this article were obtained under subprogram 01.08.01 ”Enhancing Ecological Security and the Resilience of Geo-ecosystems to Current Environmental Changes”, Stage 2 (year 2025), within the framework of developing the Management Plan for the Emerald site ”Vila Nisporeni”.*

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Received: April 07, 2026 *Accepted: July 17, 2026*

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