THE PHYSICAL, CHEMICAL AND BIOLOGICAL STATUS OF WATER BODIES IN THE JIU RIVER CATCHMENT AREA

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Abstract. Water is a renewable, vulnerable and limited natural resource at the global level, which is why it is treated as a natural heritage that must be protected and secured. In Romania, waters are part of the public domain of the state, and the "Romanian Waters" National Administration is a unique operator of water resources. The paper aims at assessing the physical, chemical and biological status of the water in the Iṣalnița reservoir under the influence of human activities, as well as developing strategies for the rehabilitation and conservation of affected aquatic ecosystems, applicable to other similar hydro-systems. The water samples were taken from the reservoir dam on a monthly basis. Thus, the pH of the water was alkaline (7.7-8.1 pH units); the oxygen level (DO 7,4-12 mg/l), BOD5 (2-4,7mg / l), COD Mn (4.2-9.3) and the conditions for nutrients determined the inclusion of the water in the 1st and 2nd category of quality, and the chlorophyll-*a* contents (44 g/l) reflect the degree of eutrophication. Their role is to highlight the functional diversity of the microbiota involved in the water biogeochemical cycles, and its pollution is a current problem, with more or less serious consequences on the population. The effects of water sources pollution are complex and varied, depending on the nature and concentration of contaminated substances (nutrients regime) which shows that in terms of saprobes, the Iṣalnița reservoir is a eutrophic lake.

Keywords: the Iṣalnița reservoir, water chemistry, degree of eutrophication, biological state, Jiu.

Rezumat. Starea fizico-chimică şi biologică a corpurilor de apă din Bazinul hidrografic Jiu. La nivel mondial, apa reprezintă o resursă naturală regenerabilă, vulnerabilă şi limitată, de aceea este tratată ca un patrimoniu natural care trebuie protejat şi apărat. În România apele fac parte din domeniul public al statului, Administraţia Naţională „Apele Române" fiind operatorul unic al resurselor de apă. Scopul lucrării de faţă îl constituie evaluarea fizico-chimică şi biologică a apei lacului artificial Iṣalnița sub influenţa factorilor antropici, având ca obiectiv elaborarea unor strategii de reabilitare şi conservare a ecosistemelor acvatice afectate, aplicabile şi în cazul altor hidrosisteme similare. Au fost prelevate lunar, probele de apă din locația baraj lac. Astfel, pH-ul apei a fost alcalin (7,7-8,1 unităti pH); regimul de oxigen (OD 7,4-12mg/l), CBO5 (2-4,7mg/l), CCO-Mn (4,2-9,3) şi regimul de nutrienți încadrează apa în categoria a I-a şi a II-a de calitate, iar conţinutul de clorofilă *a* (44µg/l) reflectă gradul de eutrofizare. Acestea au rolul de a evidenţia diversitatea funcţională a microbiotei implicate în ciclurile biogeochimice din apă, iar poluarea acesteia este o problemă actuală, cu consecinţe mai mult sau mai puţin grave asupra populaţiei. Efectele poluării surselor de apă sunt complexe şi variate, în funcţie de natura şi concentraţia substanţelor impurificatoare (regimul nutrienților) ceea ce ne evidențiază că din punct de vedere saprobiologic, acumularea Iṣalnița este un lac eutrof.

Cuvinte cheie: acumularea Iṣalnița, chimismul apei, grad de eutrofizare, stare biologică, Jiu.

INTRODUCTION

The Water Framework Directive 2000/60/EC is a new approach in the field of water management, based on the basin principle and imposing strict deadlines for the implementation of the program of measures. The main objective of the Water Framework Directive (WFD) is to achieve "good status" of all water bodies, both for surface water and groundwater, with the exception of heavily modified and artificial bodies, for which "good ecological potential" is defined. According to this Directive, European Union Member States had to ensure that all surface waters were in good condition by 2015. In Romania, water quality is monitored according to the structure and methodological principles of the Integrated Water Monitoring System in Romania (SMIAR), restructured in accordance with the provisions of European Directives (GIANFREDA & BOLLAG, 1996; GAVRILESCU & GAVRILESCU, 2009; BREZEANU et al., 2011).

The Iṣalnița reservoir is part of the ROSCI0045 protected site - Jiu Corridor and has an area of 108.73 km^2. It is located on the Jiu River, cadastral code VII, approximately 12 km upstream of the Craiova Municipality and 99.5 km from the confluence with the Danube. It has the following hydrotechnical functions: cooling water supply of the CET I Iṣalniţa thermal power plant - 33.33 m^3/s; cooling water supply of the CET II Craiova-Şimnic thermal power plant - 0.67 m^3/s; water supply of the water treatment plant belonging to the Craiova Water Supply Company - 1.15 m^3/s; the attenuation effect of the tributary floods in the dam section (Fig. 1). The Iṣalniţa water intake dam, put into use in 1964, is a hydrotechnical node composed in principle of a water intake dam with 7 openings having as main role the raising of the Jiu river water level in order to gravitationally divert a water flow to a desanding battery and to decant the water which has several uses: water supply for drinking (approximately 1200 l/s of water are collected) for the catchment, treatment and distribution system of drinkable water for the population of Craiova municipality. At the same time, it is captured for industrial purposes, in order to ensure the proper functioning of the Iṣalnița western industrial platform. Another essential role of the Iṣalnița reservoir was and it is to ensure the possibilities and the minimum conditions required to monitor the quantity and quality of water in the control system section (Fig. 2).

Figure 1. The Işalnița Dam (from Google Earth, accessed: March 11, 2020).

Figure 2. The Işalnița water intake dam (original).

The clogging of the Işalnița reservoir is closely related to erosion and natural eutrophication. Their combined actions can contribute to the growth of the sediment load of the reservoir and favour the excessive development of vegetation, and the natural eutrophication occurs as a result of the organic load thereof.

Eutrophication occurs especially during the summer, when the concentrations of nutrients in the water at high temperatures increase. The accumulation of organic matter, the increase in the amounts of nutrients, such as nitrogen and phosphorus, lead to the abundant development of various microorganisms that consume large amounts of oxygen in water.

The human settlements in the vicinity of the protected natural area do not have an adequate collection and treatment system for domestic wastewater. The domestic wastewater can reach, through the process of percolation or by surface runoff, the basin of the Işalnița reservoir, contributing to the decrease of water quality. To mitigate the effects of

this pressure, projects must be implemented which aim to equip the localities with an appropriate unitary system of wastewater collection and treatment. This form of impact was considered a pressure on the protected natural area, as a result of the observations in the field: the localities and the configuration of the neighboring lands. Also, the clogging of the lakes is accelerated by the eutrophication process, which results in the exaggerated development of the marsh and submerged vegetation. The process can be slowed down by oligotrophication processes which consist in dredging the alluvium, restoring water circulation, suppressing marsh and submerged vegetation, etc. Given this reservoir conditions, the abundance of wetland and aquatic macrophytes was found (*Phragmites communis*, *Typha angustifolia*, *Butomus umbellatus*, *Carex riparia*, *Ceratophyllum submersum*, *Myriophyllum spicatum*), while the planktonic and benthic species of the zoocoenosis are typically stagnofile (CIOBOIU, 2011; CIOBOIU & CISMAȘIU, 2016).

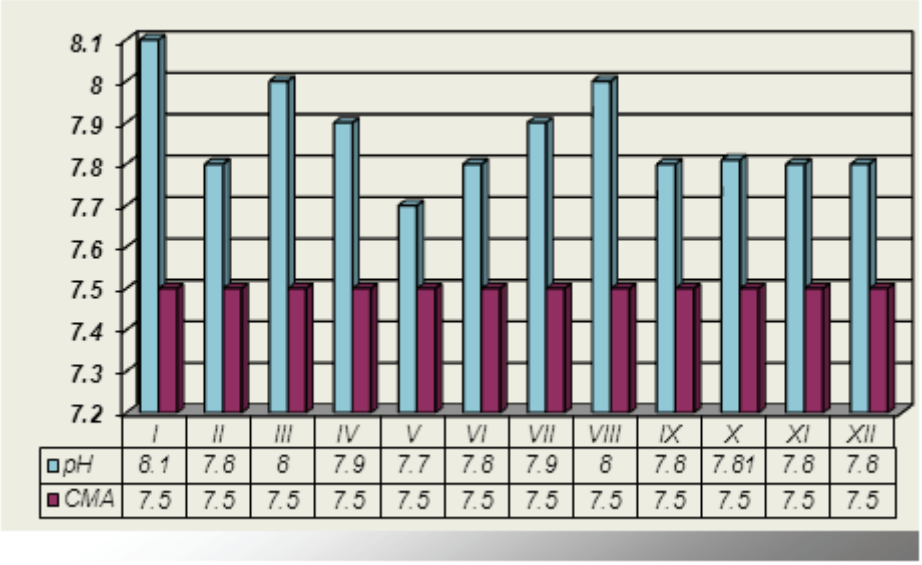
MATERIALS AND METHODS

The study was conducted in 2019 and consisted of evaluating the water quality in the Işalniţa reservoir. Samples were taken from the reservoir dam throughout the year, being presented as monthly average values. In order to establish the influence of abiotic factors on the density and composition of the studied microbial communities, the following physico-chemical parameters were determined: temperature (T^0C), pH SR ISO 10523 1997 (Hanna pH meter), filterable residue dried at 105^0 C STAS 9187: 1984, dissolved oxygen (DO_2), biochemical oxygen demand BOD (CBO5), amount of organic matter, determined by COD-Mn, total mineral nitrogen (total N), nitrates, nitrites, ammonium, sulphates, total phosphorus (total P), by using the DR2010 spectrophotometer, chlorophyll a SR ISO 10260-1996 (CUȘA, 1996; COJOCARU, 2005; BUCUREȘTEANU et al., 2007; CISMAȘIU, 2012; CIOBOIU et al., 2016).

RESULTS AND DISCUSSIONS

The continental climate is characteristic to plain areas. The area is exposed to very cold continental air invasions (-10 … -20^0C) and very hot summer invasions (30 - 35^0C), thus being characterized by an increased temperature amplitude during the year. The climate is temperate continental with Mediterranean influence, with hot and dry summers, relatively cold winters, short springs and long autumns. The multiannual average of temperature is 10.8^0C. Precipitations record a multi-annual average of 509 mm, with a maximum of rainfall in the warm period (June). The winds with the highest intensity and frequency are those from the eastern sector (24.6% with 4.3 m/s) (VLĂDUȚ, 2003; MARINICĂ et al., 2019).

The water chemistry is specific to eutrophic ecosystems (POSTOLACHE, 2006; GAVRILESCU & POPESCU, 2012; CIOBOIU, 2014). The pH values indicate a weakly basic character of water (Fig. 3).



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
pH	8.1	7.8	8	7.9	7.7	7.8	7.9	8	7.8	7.81	7.8	7.8
CMA	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5

Figure 3. The average monthly pH values in the Işalnița dam section.

The oxygen regime. The dissolved oxygen content ranged from 7.4 mg/l in June to 12.9 mg/l in January. The amount of oxygen depends on the water temperature, the partial pressure of oxygen in the air and the content of reducing substances. The decrease below the 7 mg/l limit leads to the loss of the freshness of the water, reducing the self-purification capacity and favouring the persistence of pollution triggering all the undesirable consequences (Fig. 4). The content of dissolved oxygen determines the inclusion of the reservoir water in the third category of quality. The biochemical oxygen demand is considered a means of assessing the biochemical oxygen consumption rate and depends on the current water body temperature, water movements, sunlight, oxygen concentrations, biological populations (including planktonic algae and root of plants) and the effect of the deposits from the deep waters.

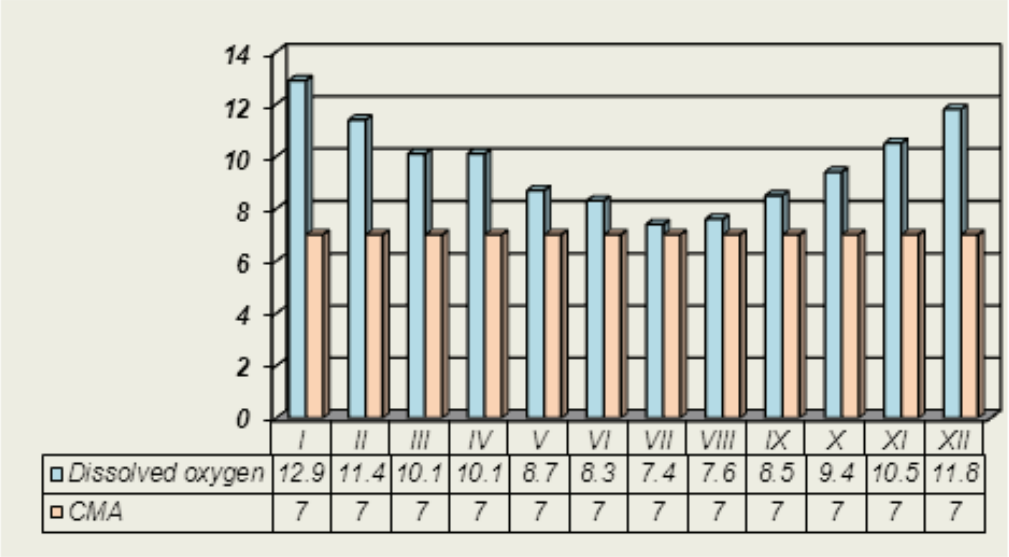


Figure 4. The average monthly values of the amount of dissolved oxygen in the Iașlnița dam section.

The polluting effect of a water body can be considerably modified by the photosynthetic action of plants and algae. CBO_5 also gives us indications on the transformation of organic nitrogen and ammonia, their nitrites and their nitrates with the help of nitrifying bacteria. Its low content highlights the existence of organic matter (Fig. 5).

The chemical oxygen demand (COD-Mn) records values above the permissible limit (3 mg/l in most months, but the maximum value is recorded in September (9.3 mg/l), which shows the presence of oxidizable substances in water and water pollution with germs that usually accompany them, including pathogenic ones (Fig. 6).

The biochemical consumption of oxygen (CBO_5) in water is included in the 2nd category, except for the month of September (4.7 mg/l) (Fig. 5).

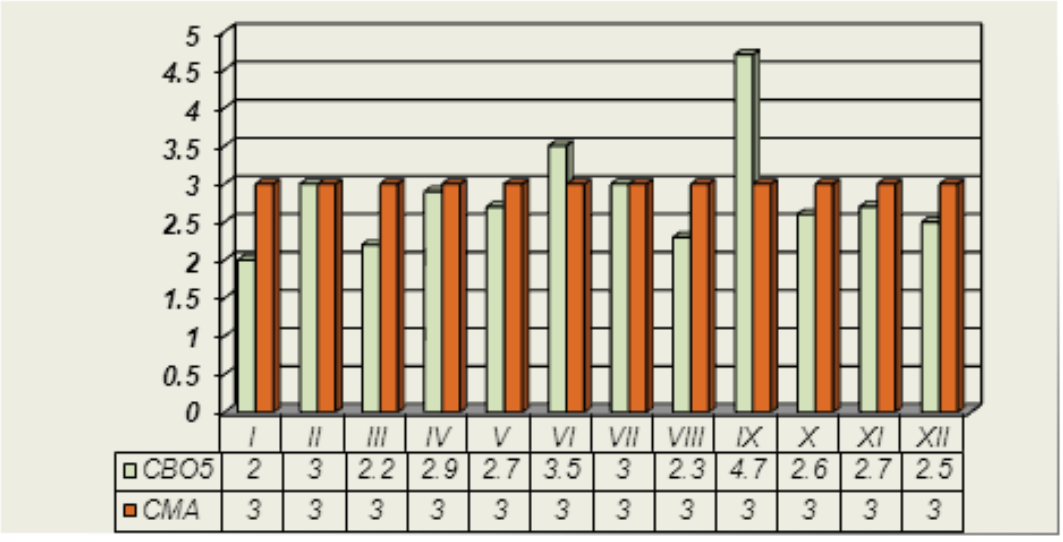


Figure 5. The average monthly values of biochemical oxygen demand CBO_5 in the Iașlnița dam section.

The chemical oxygen consumption (COD-Mn) recorded high values in September (9.3 mg l compared to 5 mg/l - MPC) – the 1st and 2nd quality category (Fig. 6).

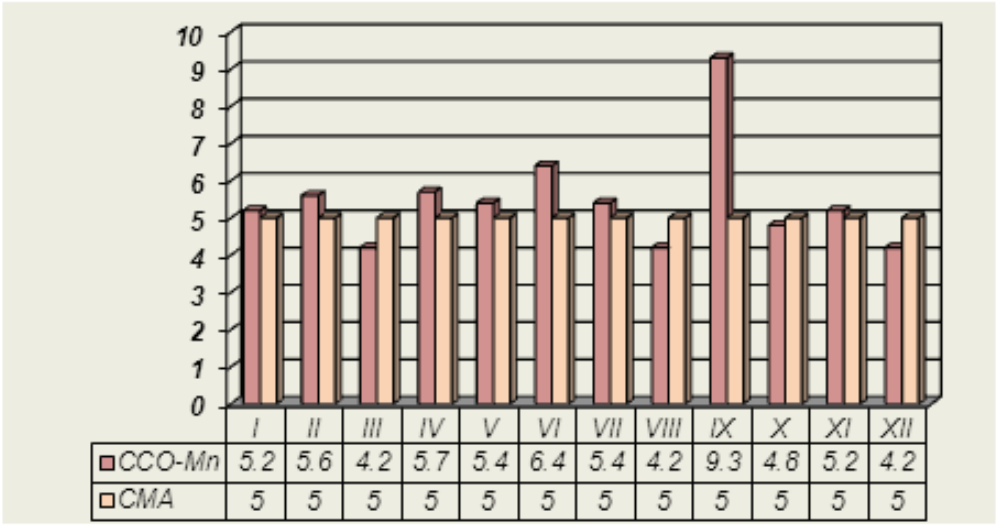


Figure 6. The average monthly values of chemical oxygen demand COD-Mn in the Ișalnița dam section.

The nutrient regime. The determination of nitrogen compounds is very important for establishing the potable conditions of water sources. The ammonium ion content is highlighted due to the decomposition stage of organic substances, which indicates recent pollution and which is consequently very dangerous. In this case we do not have values that exceed the MPC (maximum permissible concentration).

Nitrates are formed by oxidation of ammonia or by oxidation of nitrates. The conducted determinations show that they do not exceed the MPC. Nitrates constitute the final stage of oxidation of organic nitrogen, as the pollution with these substances expands and extends with the use of nitrogen fertilizers in order to increase the agricultural production. They are also the final product of aerobic decomposition of organic matter. They can also come from domestic waters. The recorded values exceed the MPC due to either leaching or infiltration of water rich in nitrogen fertilizers, or due to nitrification of organisms.

The total nitrogen (analysed in terms of NH_4, NO_2 and NO_3) falls within the permitted limits, with the exception of NO_3 , and the phosphorus exceeds these values (values of 0.25-0.34 mg/l were recorded compared to 0.1 mg/l-MPC), as these elements generally are the first eutrophic factors. In terms of nutrients, in both monitoring sections, the water quality is included in class I. The average monthly values of ammonium ion – NH_4 for 2019 compared to MPC are within the limits allowed according to Order 1146/2002 (Fig. 7).

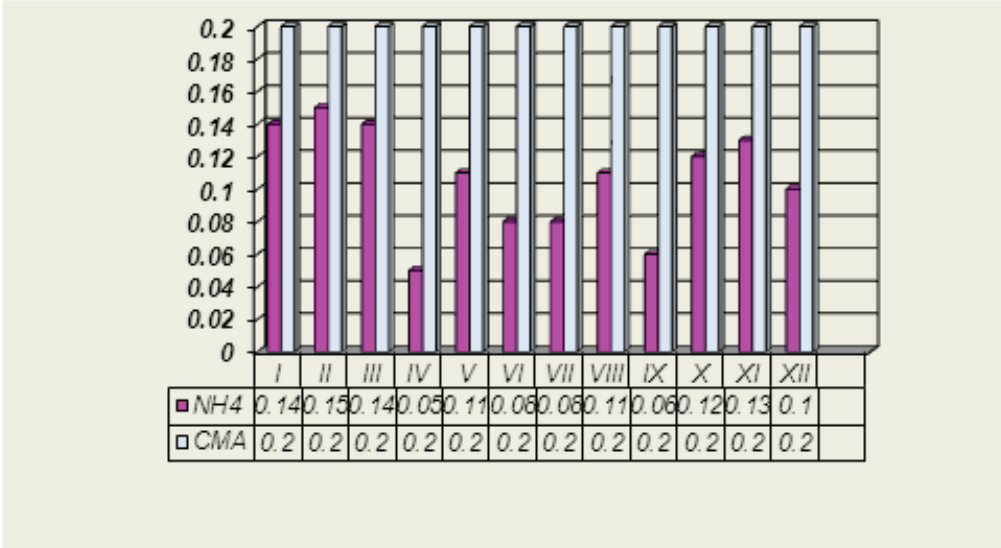


Figure 7. The average monthly values of ammonium ion - Ișalnița dam section.

The average monthly values of NO_2 for 2019 compared to MPC according to Order 1146/2002 include the waters in the 1st and 2nd quality category (Fig. 8).

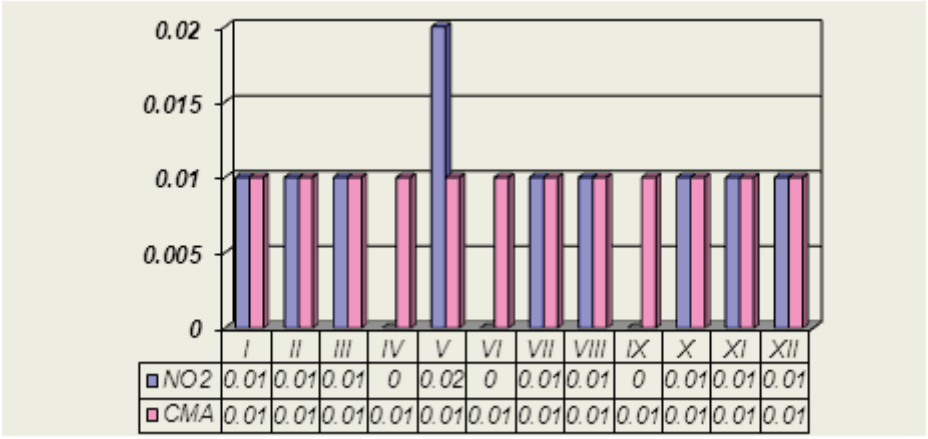


Figure 8. The average monthly values of nitrites (NO_2) - Iașlnița dam section.

The average monthly values of NO_3 for 2019 compared to the MPC are within the limits allowed according to Order 1146/2002 (Fig. 9).

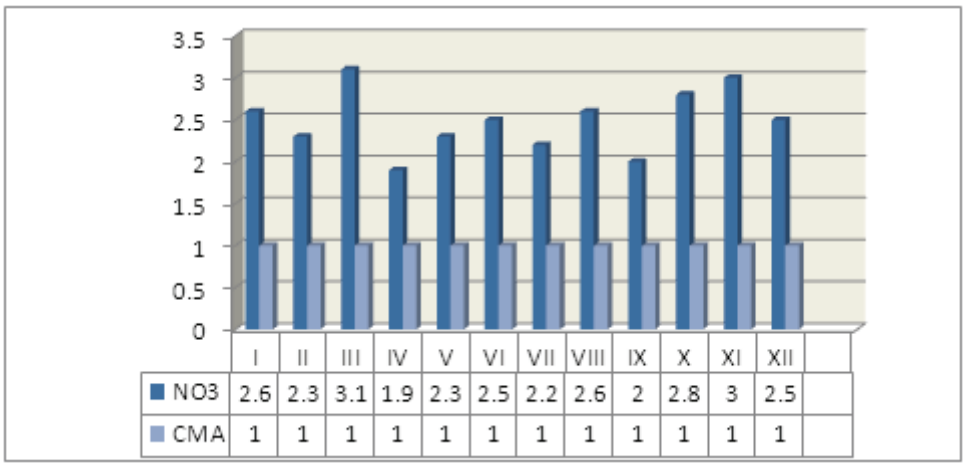


Figure 9. The average monthly values of nitrates (NO_3) - Iașlnița dam section.

The phosphorus is related to organic compounds from diffuse pollution in agriculture, due to the administration of nitrogen and phosphorus fertilizers, as well as the presence of detergents. The presence of phosphorus in water favours its eutrophication, causing algal growth. The obtained values can also be correlated with the development of microbial fauna (Figs. 10; 11).

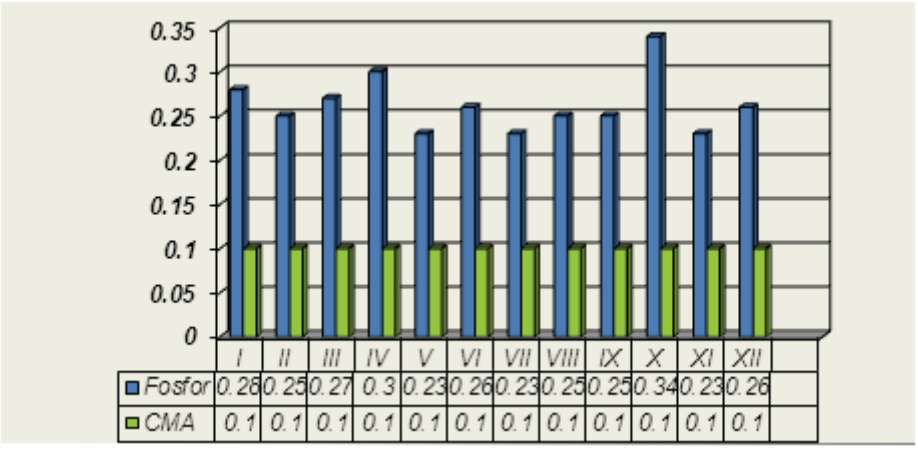


Figure 10. The average monthly values of phosphorus - Iașlnița dam section.

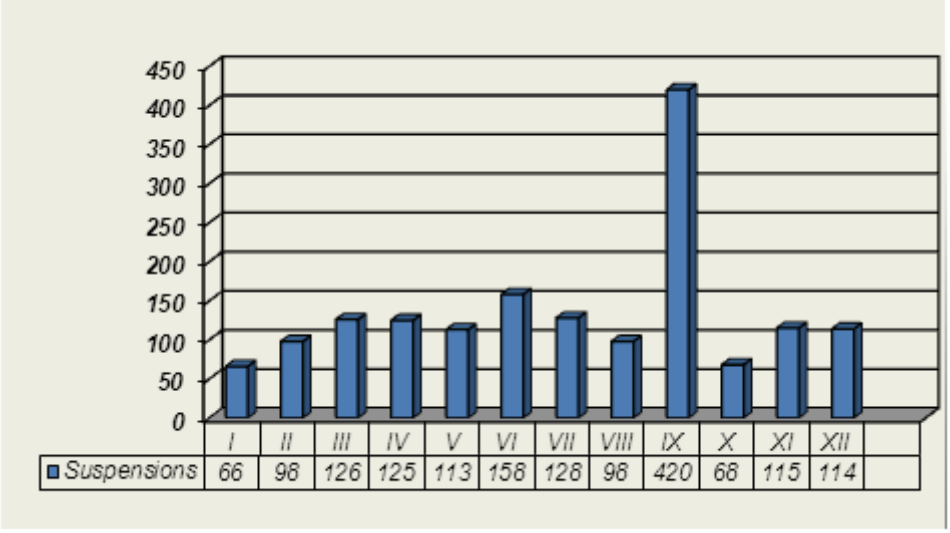


Figure 11. The average monthly values of suspensions - Ișalnița dam section.

The saprobiological characterization of the Ișalnița reservoir. Being located on the Jiu River at the lower limit of the Getic Piedmont (85.5 m altitude), upstream of the city of Craiova, the Ișalnița reservoir with an average depth of 3.1 m is the only surface water body with drinking water in the analyzed catchment area. From a saprobiological point of view, the Ișalnița reservoir is a eutrophic lake with average values of phytoplankton biomass (1549 mg/l) and chlorophyll a (3 µg/l) in 2019 (Fig. 12). The dominant species in phytoplankton belong to the bacillariophytes (*Gyrosigma acuminatum, Asterionella gracillima, Ceratoneis arcus, Diatoma vulgare, Meridion circulare, Tabellaria flocculosa, Pinnularia viridis, Navicula gracilis, Cymatopleura solea, Synedra acus*) with an average annual density of 406 350 ex/l. The mineralization processes of the organic matter deposited on the lake bottom are reduced, which leads to accumulations of sapropelic mud in very large quantities (COJOCARU et al., 2007; BREZEANU et al., 2011; CIOBOIU et al., 2017).

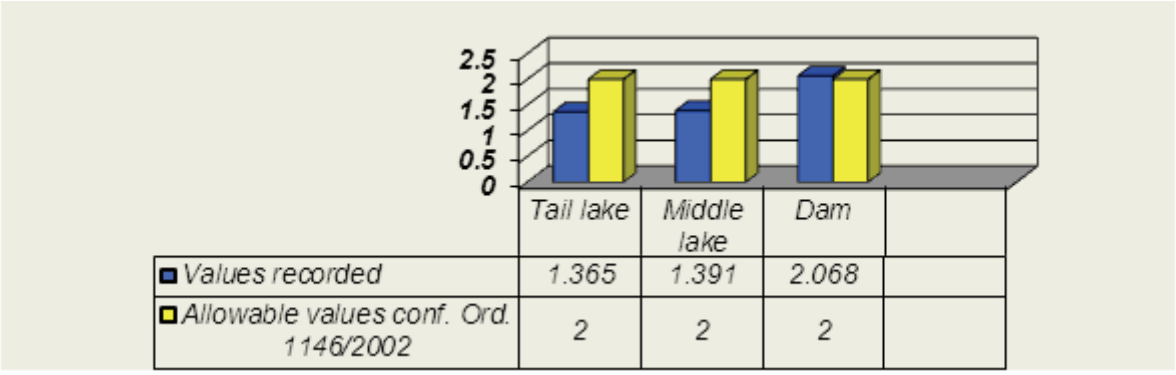


Figure 12. The average annual values of the phytoplankton biomass.

The biological qualitative elements. The method of saprobes and its application in assessing the state of ecosystems is particularly important because it is the main indicator that reflects the degree of water bodies pollution with organic substances, but also the structure of life in water. According to the degree of loads with organic matter and according to the physico-chemical characteristics, it was found that in the dam area of the Ișalnița reservoir, the phytoplankton biomass has average values of 1.71 mg/l, chlorophyll a - 23.23 µg/l, total phosphorus ($_{total}$P) - 1.77 mg/l and total mineral nitrogen - 1.53 mg/l, values that fall into the oligotrophic-eutrophic category (FAUR & GEORGESCU, 2009; GAVRILESCU, 2011; PĂCEȘILĂ, 2012).

The degree of eutrophication of the Ișalnița reservoir was established on the basis of biological elements (maximum biomass of phytoplankton and average annual chlorophyll a), minimum oxygen saturation and on the basis of total nitrogen and total phosphorus nutrients (Table 1).

Table 1. The degree of trophicity of the Ișalnița reservoir I.

Ișalnița Reservoir I	**Minimum oxygen saturation%**	**Maximum phytoplankton biomass mg/l**	**Average annual chlorophyll *a* mg/l**	**$_{total}$ N (average value) mg/l**	**$_{total}$ P (average value) mg/l**
Results	81.1	22.56	44.13	1.860	0.280
Degree of trophicity	Oligotroph	Hypertrophic	Hypertrophic	Hypertrophic	Hypertrophic

In terms of the load with total nitrogen and total phosphorus (average values), of the maximum biomass of phytoplankton and of the annual average chlorophyll a, the reservoir has hypertrophic characteristics in 2019, and in terms of the minimum oxygen saturation it has eutrophic characteristics (SANDU et al., 2004; PUSKÁS et al., 2005). Analysing the average values of total phosphorus, it is found that in the same year it falls into the category of hypertrophic lake (Table 2).

Table 2. The degree of trophicity of the Ișalnița reservoir II.

Ișalnița Reservoir II	**Minimum oxygen saturation%**	**Maximum phytoplankton biomass mg/l**	**Average annual chlorophyll *a* mg/l**	**$_{total}$ N (average value) mg/l**	**$_{total}$ P (average value) mg/l**
Results	58.64	10.35	33.56	1.770	0.096
Degree of trophicity	Eutrophic	Eutrophic	Hypertrophic	Hypertrophic	Hypertrophic

The trophic state of the reservoir has a dynamic character determining the ecological succession, as the process of enrichment with organic matter leads to the transition from the oligotrophic state to the eutrophic one (Tables 3; 4).

Table 3. The chemical indicators of the Ișalnița reservoir.

Ișalnița reservoir	**Indicators**	**Values (µg/l)**
1	Non-algal turbidity	0.08
2	$_{total}$ P	255
3	$_{total}$ N	1730
4	Chlorophyll *a*	45130
5	Secchi depth	0.3
6	Organic nitrogen	200
7	Orthophosphate	0.6

Table 4. The trophic characterization of the Ișalnița reservoir.

Planktonic and benthic communities	**Good condition**	**Average condition**
Phytoplankton	Compared to specific communities of this type, there are slight changes in the composition and taxonomic abundance of the plankton. These changes do not indicate an accelerated growth of algae leading to undesirable distortions of the balance of organisms present in the water body or of the physico-chemical quality of the water or sediment. There may be a slight increase in the frequency and intensity of plankton efflorescences specific to that type.	The composition and taxonomic abundance of plankton differ moderately from communities specific to this type. The biomass is moderately deformed and can produce a significant undesirable deformation in the status of other biological qualitative elements and the physico-chemical quality of water or sediments. A moderate increase in the frequency and intensity of plankton efflorescences may occur. Persistent efflorescences of plankton may appear in the summer months.
Macrophytic and phytobenthic vegetation	Compared to specific communities of this type, there are slight changes in the composition and abundance of phytobenthic and macrophyte taxonomy. These changes do not indicate an accelerated growth of phytobenthic vegetation or higher plant forms leading to undesirable distortions of the balance of organisms present in the body of water or of the physico-chemical quality of the water. The phytobenthic community is not adversely affected by bacterial bundles or shells present as a result of anthropogenic activity.	The phytobenthic and macrophyte taxonomic composition differs moderately from the communities specific to this type and is much more deformed than in the case of those in a good condition. There are moderate changes in the average macrophyte and phytobenthic abundance. The phytobenthic community may be combined and, in certain areas, replaced by bacterial bundles or shells present as a result of the anthropogenic activity.

Benthic invertebrate fauna	Compared to communities specific to this type, there are slight changes in the composition and taxonomic abundance of invertebrates. The level of taxonomic diversity for invertebrates indicates slight signs of change in comparison to the levels specific to this type. The ratio between change-sensitive and insensitive taxonomic categories shows slight changes compared to undisturbed levels.	The composition and taxonomic abundance of invertebrates differ moderately from communities specific to this type. Major community-specific taxonomic groups are absent. The ratio between the taxonomic categories that are sensitive to change and the insensitive ones, as well as the level of diversity are substantially lower than the specific levels of this type and clearly lower than the levels of those in a good condition.

Effects and consequences on the environment. The biological-ecological analysis of water is based on all the responses of organisms to environmental conditions. Following the gradual change in the physico-chemical characteristics of water as a result of pollution, there is a change in ecological balance, based on advantages and disadvantages due to the effects and consequences resulting from the degree of intoxication of the studied ecosystem (BREZEANU et al., 2011).

Among the effects we can mention: the continuous clogging of the reservoir due to the lowering of the energy of the water stream and of its capacity to transport the sediments; shoreline plating and water flow direction, which affect the biodiversity and the natural environment, but are compensated by the cessation of erosion-based losses of land; erosion of the riverbed downstream of the dam due to the intensely turbulent nature of the flow.

The consequences consist in: not ensuring the possibilities and technical conditions for flood mitigation; affecting microbiological processes and phenomena, significant changes in the conditions of maintenance and development of microorganisms, aquatic flora and fauna; weighting the requirements for the achievement of the provisions from the water management plans and programs, and of the drought plans; the need for permanent dredging in front of the water intake dam to ensure the water flow; special technical and financial efforts (GAVRILESCU & GAVRILESCU, 2007).

CONCLUSIONS

The Ișalnița reservoir located in the lower sector of the Jiu River belongs to the category of eutrophic ecosystems within the hydrographic network of Romania. The water chemistry determined by alkaline pH values (7.7-8.1 pH units), oxygen regime (OD 7.4-12mg / l), CBO5 (2-4.7mg / l), COD -Mn (4.2-9.3) and the nutrient regime include water in the 1st and 2nd category of quality, and the chlorophyll a content (44 µg/l) reflects the degree of eutrophication. The clogging of the reservoir is closely related to soil erosion and natural eutrophication. From a saprobiological point of view, according to the degree of loads with organic matter and according to the physico-chemical characteristics, it was found that in the dam area of the Ișalnița reservoir, the phytoplanktonic biomass has average values of 1.71 mg/l, chlorophyll a - 23.23 µg/l, total phosphorus ($_{total}$P) - 1.77 mg/l and total mineral nitrogen - 1.53 mg/l, values that fall into the oligotrophic-eutrophic category. The planktonic and benthic communities are influenced by the physico-chemical qualities of the water or sediments, and by the anthropogenic impact.

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