THE IMPACT OF CLIMATIC AND TECHNOGENIC FACTORS ON THE SEASONAL DYNAMICS OF PHYSICO-CHEMICAL PARAMETERS OF THE DNIESTER AND PRUT RIVERS

JURMINSKAIA Olga, BAGRIN Nina, ZUBCOV Elena

Abstract. The functioning of aquatic biocenoses is directly related to the climatic conditions of a certain ecoregion. Climate change in recent decades has resulted in the blurring of the boundaries between seasons. However, regardless of what factors have caused modifications in the temperature regime of an aquatic ecosystem (climatic or technogenic), it will result in the disruption of natural seasonal cycles of hydration development and reproduction. This paper presents an analysis of the seasonal dynamics of main physico-chemical parameters of the Dniester and Prut rivers in the Republic of Moldova for the 2022 vegetation season.

Keywords: aquatic ecosystems, climate changes, hydropower impact.

Rezumat. Impactul factorilor climatici și tehnogeni asupra dinamicii sezoniere a parametrilor fizico-chimici ai râurilor Nistru și Prut. Funcționarea biocenozelor acvatice este direct legată de condițiile climatice ale unei anumite ecoregiuni. Schimbările climatice din ultimele decenii au dus la estomparea granițelor dintre anotimpuri. Dar, indiferent de factorii care au cauzat modificări ale regimului de temperatură al ecosistemului acvatic (climatici sau antropogeni), rezultatul este perturbarea ciclurilor sezoniere naturale de dezvoltare și reproducere a hidrobionților. Lucrarea de față prezintă o analiză a dinamicii sezoniere a principalilor parametrii fizico-chimici ai râurilor Nistru și Prut din Republica Moldova pentru sezonul de vegetație 2022.

Cuvinte cheie: ecosisteme acvatice, schimbări climatice, impact hidroenergetic.

INTRODUCTION

River ecosystem functioning will be sustainable if its biotic component (microorganisms, primary producers, invertebrates, fish and other vertebrates) can adapt to the climatic conditions of the ecoregion as well as to the hydro-morphological and physical and chemical parameters of an watercourse. According to the WFD methodology, biological elements are a priority in the ecological classification of surface water bodies. Hydro-morphological and physico-chemical elements are considered as necessary conditions for functioning of the biological elements (***. WFD: Ecological Status, 2003). Prolonged changes in any abiotic factor lead to successions in the biotic communities of the water body. If changes persist, new biocenoses adapted to new habitat conditions are formed. For running water bodies, such factors are: water transparency, flow velocity, substrate structure and its variations, temperature and oxygen regimes, content of nutrients, organic pollutants, toxic substances, etc.

One of the most significant challenges of the 21st century has been climate change, which triggers alterations in ecosystem functioning and loss of biodiversity (OZBAYRAM at al., 2022). These changes affects the state of surface waters at different levels: both at the level of the water body and at the basin level as a whole. Hydrological droughts in recent years have become a common phenomenon in Moldova not only in summer and autumn; but also in winter and even in spring (JURMINSKAIA et al., 2020a). Many small rivers dry up partially or completely in the summer, and the level of the main water arteries of the Republic of Moldova - the Dniester and Prut rivers - drops critically.

An equally significant problem for river ecosystems is the impact of hydrotechnical facilities, such as hydroelectric power plants (HPPs) with their dams, turbines, technological reservoirs, diurnal fluctuations in water level, etc. A prominent example is the impact of the Dniester Hydropower Complex (Ukraine) on the Moldovan part of the Dniester River, namely: the modification of the hydrological regime and the disruption of the natural seasonal dynamics of water temperature caused not only a change in the gas regime of the river; but also a reduction of its productivity potential (ZUBCOV et al., 2021).

The aim of the presented work is to analyse the current state of the Dniester and Prut rivers in terms of the seasonal dynamics of main physico-chemical parameters, such as water temperature, acidification and dissolved oxygen, on an example of the vegetation period of 2022.

MATERIAL AND METHODS

Six seasonal expeditions (spring - summer - autumn) were carried out on the Dniester and Prut rivers within the territory of the Republic of Moldova. Water samples and biological material were collected for hydrobiological, ecotoxicological, hydrochemical and microbiological studies under laboratory conditions. Some physico-chemical parameters of water were measured "in situ".

In the Prut River basin, samples were collected at the following stations: Costești (Costești-Stinca Reservoir dam), Braniște, Sculeni, Leușeni, Cahul, Caslita-Prut and Giurgiulești. In the Dniester River basin, the sampling was performed from the right riverside at the following stations: Naslavcea, Soroca, Camenca (Middle Dniester), Hirjau, Goian, Cocieri (Dubossary Reservoir), Vadul lui Voda, Varnita, Palanca (Low Dniester). A total of 275 results of physico-chemical analyses (150 for the Dniester River and 125 for the Prut River), obtained during the hydrological vegetation period 2022, were analysed graphically. In addition, a retrospective statistical analysis (2013 - 2022) of the temperature regime at selected target sites of these rivers was carried out using the database of the Laboratory of Hydrobiology and Ecotoxicology of the Institute of Zoology. Graphical and statistical data processing was performed in Microsoft Excel.

The result of pH measurement by electrometric method is not influenced by colour, turbidity, free chlorine or the presence of reducing or oxidising substances, but depends on the temperature of the sample. Therefore, pH measurement in aquatic ecosystem monitoring programmes is carried out "'in situ" (***. Hydrochemical and hydrobiological sampling guidance, 2015). The multi-parameter analyser CONSORT C5030 was used.

Determination of dissolved oxygen concentration was performed according to the national standard (***. SM SR EN 25813, 2012) using the Winkler method. In parallel, oxygen concentration in water was measured "in situ" with the Multi-sensor Measuring Instrument MS 08. Water temperature was measured at a depth of 80 – 100 cm of the water layer using the hydrological thermometer with a graduation value of 0.1ºC. In parallel, the water temperature was controlled with CONSORT C5030 and MS 08 portable equipment.

RESULTS AND DISCUSSIONS

The functioning of aquatic biocenoses is directly related to climatic conditions during a certain season of the hydrological period (PLETTERBAUER at. al., 2018). This makes it necessary to characterise, at least in general terms, the weather conditions of 2022 for the hydrological situation in the Republic of Moldova. Due to the lack of good snow cover in the Carpathians, the volume of the Spring High Waters on the rivers Dniester and Prut in 2022 was not significant (Fig. 1).

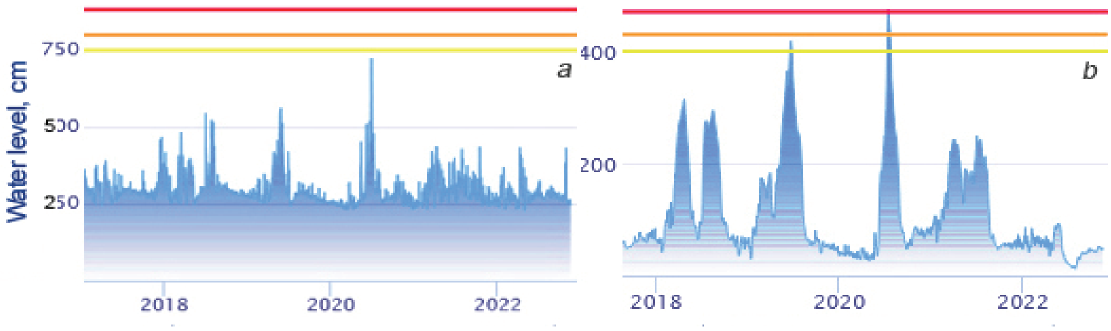

Figure 1. Water levels in the Dniester and Prut rivers in 2022 compared to previous years:
a – Dniester River, Hrusca Hydrological Post; *b* – Prut River Brinza Hydrological Post (SHS, a).

According to State Hydrometeorological Service data, the spring of 2022 was heterogeneous in terms of thermal regime and precipitation amounts. In May (spring expedition), the hydrological regime of the Dniester and Prut rivers was characterized by a low level. The amount of precipitations on most of the territory of the Republic of Moldova did not exceed 10 – 50 % of the monthly norm. During the summer season, the amount of precipitations in most areas of the republic did not exceed 25 – 65 % of the norm. The month of October (autumn expeditions) was characterized by warmer than usual weather and precipitation deficit. Deviations from the multiannual precipitation norm for the three hydrological seasons in 2022 are presented in figure 2.

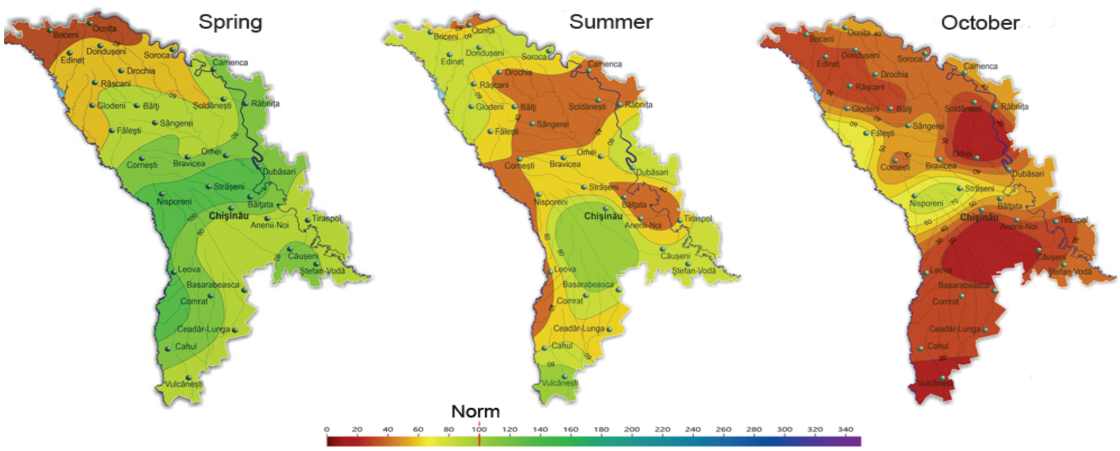

Figure 2. Deviation from the multiannual precipitation norm (%) in 2022 (SHS, b).

Water temperature: seasonal dynamics. Water temperature plays crucial role in the seasonal cycles of the development of hydrobionts. Moldova's two main waterways, the Dniester and the Prut rivers, have very similar natural hydro-morphological parameters: their headwaters are located in the Carpathians, their middle reaches cross the same ecoregion – the Eastern Plains, and the estuaries of both rivers are located in the Northern Black Sea area (between 45º and 46º North latitude). Thus, the climatic conditions for these aquatic ecosystems are similar. Similar is also the fact that both ecosystems are affected by anthropogenic pressures aggravated by the construction of HPPs.

The Prut River is a transboundary watercourse between Romania and the Republic of Moldova for 695 km (up to its confluence with the Danube River). Between the localities of Costești (Moldovan bank) and Stinca (Romanian bank), the river was barraged during 1973 – 1978 by the dam of Costești-Stinca Hydropower Plant. As a result, the accumulating artificial reservoir on the Prut River was formed, which is in common use by Romania and Moldova.

The Dniester River is also a shared watercourse for Ukraine and the Republic of Moldova. Its first regulation was implemented on the territory of Moldova in 1951 – 1954 by the dam of Dubossary HPP, as a result of which the flow-riverbed Dubossary reservoir was formed. In 1981, the construction of the Dniester Hydropower Complex (DHPC) began on the territory of Ukraine. Currently, the DHPC includes: the Dniester Reservoir with the Hydropower Plant 1 (HPP-1), the buffer reservoir with the HPP-2 and the Pumped Storage Hydropower Plant (PSHPP) with its technological reservoir. Thus, the Dniester water is pumped from one technological reservoir to another to produce electricity at the PSHPP, after which it is discharged through the HPP-2 dam to the territory of Moldova (Naslavcea station). The production of electricity using hydropower plants is called "clean technology". The Moldovan scientists-hydrobiologists (ZUBCOV et al., 2021) disagree with this terminology, continuously proving, with concrete examples that the DHPC disrupts the Dniester ecosystem, transforming the river into a technological water.

To demonstrate the seasonal dynamics of the main physico-chemical parameters of the Dniester River current state in Moldova, the river section from Naslavcea (downstream of the HPP-2 dam) to Varnita (downstream of the Dubossary HPP dam) was chosen. For the Prut River, the section from Braniste (downstream of the Costești-Stinca HPP dam) to Giurgiulești (confluence with the Danube River) was selected.

The natural life cycles of hydrobionts are formed in the process of long-term adaptation to habitat conditions. The barraging of the river without pumping water into deep reservoirs does not critically affect the temperature regime of the watercourse downstream of the dam. An example is the seasonal dynamics of water temperature in the Prut River downstream of the Costești-Stinca HPP dam (Fig. 3, Braniște station) and the Dniester River downstream of the Dubossary HPP dam (Fig. 3, Vadul lui Voda station). The temperature regime of the Dniester water downstream of the DHPC has lost its seasonal dynamics (Fig. 3, Naslavcea station). This is manifested in the fact that the spring and summer water temperatures are lower than natural values by more than 10ºC.

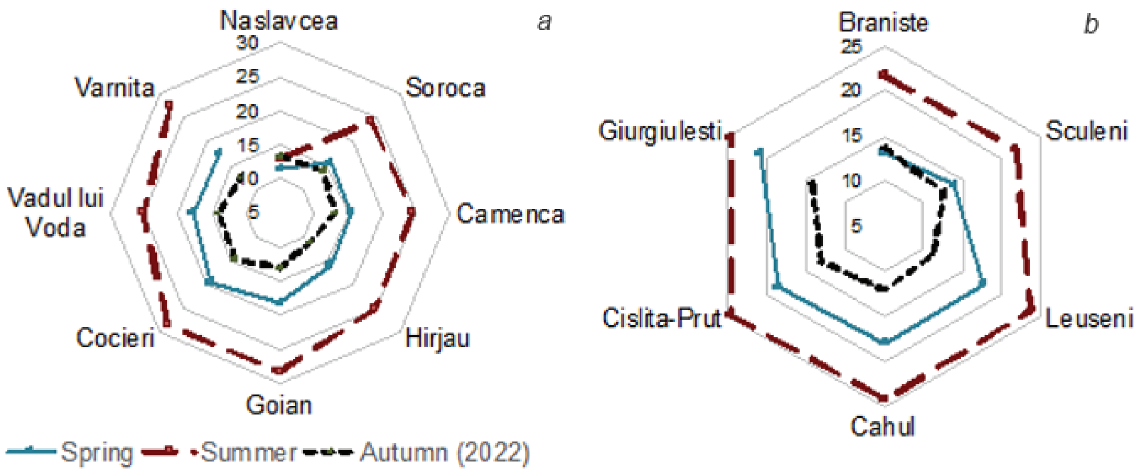

Figure 3. Seasonal-spatial water temperature dynamics (ºC) in the Dniester (*a*) and Prut (*b*) rivers.

The seasonal variation of the Prut water temperature in the analysed area could be considered as reference, except for the section Braniște-Sculeni. The river supply in this area is greatly influenced by groundwater, so the spring and autumn water temperature values are practically the same in 2022.

It is quite logical that when identifying seasonal trends, the analysis of long-term data will be more reliable. For this review, sections of the Dniester and Prut rivers were selected, where the impact of HPPs is practically not registered, i.e., the seasonal dynamics of water temperature is due to the climatic factor. These are the Goian and Sculeni stations located at the same latitude. The database of the Laboratory of Hydrobiology and Ecotoxicology for the last 10 years was used for this analysis (Table 1).

Table 1. Multiyear seasonal dynamics of water temperature in the middle course of the Dniester and Prut rivers.

River	Station	Latitude	Year	Spring	Summer	Autumn
Dniester	Goian	47° 19' 22" North	2013	8.6	28.4	14.8
			2014	14.0	22.0	13.2
			2015	13.2	27.4	15.6
			2016	10.4	24.0	10.0
			2017	9.6	25.2	13.6
			2018	8.0	26.8	17.4
			2019	18.2	25.4	13.8
			2020	15.0	24.2	15.6
			2021	6.6	24.0	13.8
			2022	15.0	28.2	13.0
			Mean ± SEM	***11.9 ± 1.19***	***25.6 ± 0.66***	***14.1 ± 0.62***
Prut	Sculeni	47° 22' 40" North	2013	11.0	25.8	13.3
			2014	14.8	25.8	15.0
			2015	7.2	22.4	12.4
			2016	6.6	26.2	10.2
			2017	10.2	24.8	12.8
			2018	10.3	22.0	13.2
			2019	18.2	23.8	15.0
			2020	17.8	21.4	18.8
			2021	10.3	24.8	11.8
			2022	17.8	23.8	11.2
			Mean ± SEM	***12.4 ± 1.39***	***24.1 ± 0.54***	***13.4 ± 0.77***

As it can be seen from the presented data, the average long-term values of seasonal water temperatures in the Dniester and Prut rivers are high and very close, differing only by 0.5°C for the spring and summer seasons and by 0.7°C for the autumn season. As for the Dniester River section downstream of the HPP-2 dam (Naslavcea - Soroca), in terms of water temperature parameter, it is a heavily modified water body (HMWB according to WFD terminology) due to the thermal pollution caused by the operation of the Dniester Hydropower Complex.

Concentration of hydrogen ions (pH value): seasonal dynamics. The pH value is very important parameter of the habitat, which determines the efficiency of hydrochemical and hydrobiological processes in aquatic ecosystems. The activity of hydrobionts and the stability of various forms of elements migration depend on the pH value. The range of 6.5 – 8.5 (pH units) has been adopted as the acceptable limit for Water Quality Class I (WQC) in many national classification systems, including the RM. Various abiotic and biotic factors influence the acidification state of surface water body. Under natural conditions (without anthropogenic impact), the concentration of hydrogen ions at a given monitoring site may be exposed to seasonal fluctuations. During the growing season, fluctuations in pH value are related to photosynthesis processes in the photic zone of a water body, provoking its alkalization. In autumn, however, the decomposition of organic biomass by aquatic microflora can create a local increase in carbon dioxide concentration, leading to an acidification of the water. Acidification of surface water bodies unrelated to the season can be triggered by acid precipitations provoked by an increase of carbon dioxide or sulphur and nitrogen oxides in the atmosphere. Persistent acidification has negative consequences, such as changes in the ionic composition of the water, transformation of metals from bound to free form and, ultimately, reducing the buffer capacity of a water body (JURMINSKAIA et al., 2020b).

The dynamics of hydrogen ions concentration in the Prut water was stable during the analyzed period 2022 (Fig. 4), slightly fluctuating within 8.15 – 8.60 (pH units), which corresponds to Water Quality Class I according to the normative documentation of the Republic of Moldova (***. Regulation, 2013). High concentration of suspended solids (recorded in May at Sculeni station) had no significant impact on the pH value, indicating the natural origin of this pollution (for example, a rain flood in the basin of the right Prut tributaries).

The dynamics of the hydrogen ions concentration in the Dniester water varied in a wider range, namely 7.74 – 9.21 (pH units) which corresponds to Water Quality Classes I – III. The highest pH values were recorded at the Goian station in May and at the Camenca station in autumn (Fig. 4). The alkalization of the water in Goian was due to the biotic factor such as the photosynthetic activity of phytoplankton and submerged macrophytes under sunny weather conditions and weak water flow at this site of the Dubossary Reservoir. As for the Camenca station, we associated the alkalization of the Dniester water with the processing season of fruit and vegetable products at the Camenca Cannery, as a result of which a large volume of manufacturing wastewater is discharged into the Dniester River without any preliminary treatment. Unfortunately, it should be noted that in the entire section of the Dniester River under consideration, sewage treatment facilities with complete biological purification operate only in Ribniţa and Chişinău. At the local manufacturing treatment facilities, built in the 60 - 90s of the last century, the treatment is performed only in the form of sedimentation.

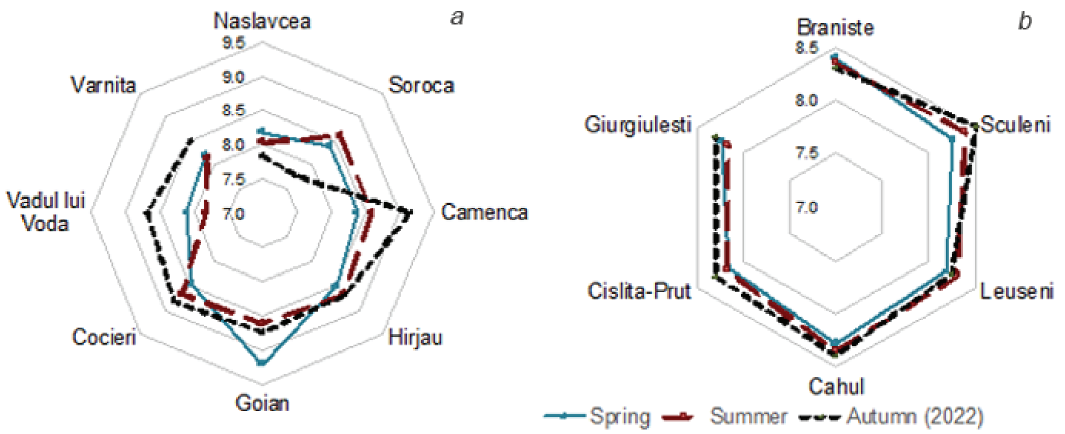

Figure 4. Seasonal-spatial dynamics of the active water reaction (pH units) in the Dniester (*a*) and Prut (*b*) rivers.

Analysis of the obtained results shows that within one vegetation period the active reaction of water in the Prut River was not exposed to any significant seasonal fluctuations. Seasonal variations in water pH values in the Dniester River occurred, but were of local nature and were provoked by various factors, both biotic and anthropogenic.

Concentration of dissolved oxygen: seasonal dynamics. Dissolved oxygen concentration in an aquatic ecosystem depends on many factors, including biotic and abiotic, natural and anthropogenic. Among natural factors, the following have the main influence on oxygen concentration: water temperature, atmospheric pressure, flow turbulence and activity of primary producers such as algae and submerged macrophytes. Primary producers can cause both local oxygen deficiency (as a result of mass extinction – secondary pollution of the habitat), and local supersaturation in shallow water bodies during calm weather. Among anthropogenic factors causing dissolved oxygen deficiency in the rivers of the Republic of Moldova, the most common is the discharge of untreated sewage water. Chemical pollutants of wastewater interact with oxygen directly, while biogenic pollution causes extensive development of relevant microflora, that significantly decrease the oxygen concentration in water. For any combination of these factors, the oxygen concentration in a water body (or its sector) is the result of a dynamic balance between the process of natural aeration (diffusion/convection), oxygen production and its consumption.

Oxygen solubility in water decreases with increasing altitude, water temperature and salinity, as well as with decreasing atmospheric pressure. Water salinity and altitude gradient have no significant effect on the solubility of oxygen in the water of the Dniester and Prut rivers within the territory of the Republic of Moldova. Thus, seasonal and spatial dynamics of dissolved oxygen concentration should be mainly due to seasonal changes in water temperature. The real situation is presented in figure 5.

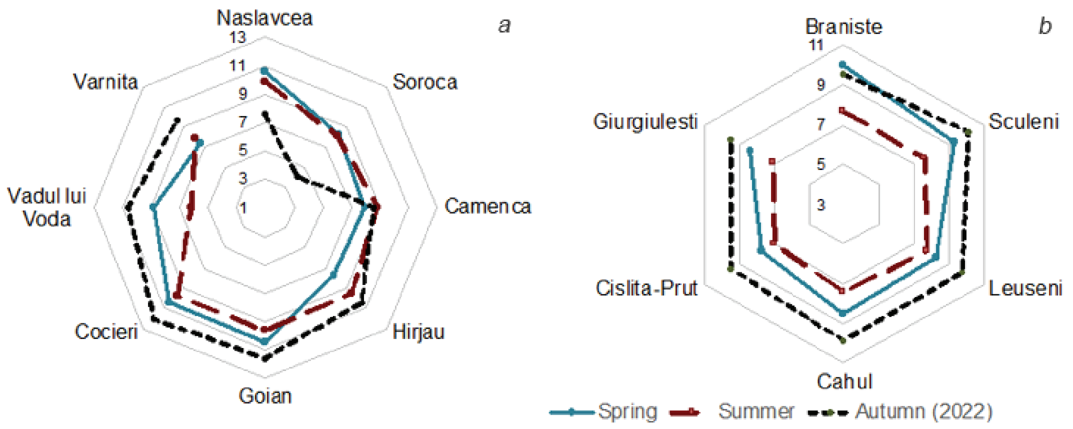

Figure 5. Seasonal-spatial dynamics of the dissolved oxygen concentration (mg/L) in the Dniester (*a*) and Prut (*b*) rivers.

Dissolved oxygen concentrations in the Prut River during the vegetation period 2022 had a natural seasonal dynamics with a very narrow range of spatial variation in summer (7.0 – 7.7 mg/L) and a slightly wider range in spring (7.8 – 10.0 mg/L) and autumn (9.5 – 10.2 mg/L). Each season is represented by its own line with natural dynamics for this parameter: the lowest values correspond to the summer season (highest water temperature), and the highest concentrations are associated with the autumn season (lowest water temperatures). Thus, the seasonal dynamics of dissolved oxygen and water temperature parameters have a natural inverse correlation that ensure the sustainable functioning of the Prut River ecosystem.

As for the Dniester River, the natural seasonal dynamics of oxygen concentration was observed only in two locations: at Goian and Cocieri stations in the lower section of the Dubossary reservoir. At other stations (Naslavcea, Soroca, Camenca, Hirjau, Vadul lui Voda, Varnita) fluctuations of the dissolved oxygen in water had no seasonal trends. This can be explained by the cumulative effect of several factors: in Naslavcea it is the result of thermal pollution; in Soroca and Varnita – of the discharge of untreated wastewater; in Vadul-lui-Voda – of the shoaling of the river (to the extent that the water intake pipes became visible) as a result of hydrological drought, etc.

According to both the results of 2022 and data of previous years, the Naslavcea-Soroca section is the most vulnerable, where water oxygen saturation sometimes does not exceed 40 %. Long-term oxygen deficiency is a limiting factor for various groups of hydrobionts in both lentic and lotic ecosystems. As for the water bodies in question, the critical seasons in which oxygen deficiency can occur are winter and summer. However, under the current challenges (impact of hydrological droughts, discharge of untreated wastewater, functioning of the Dniester Hydropower Complex), any season, even spring and autumn, can become critical for the hydrobionts of the Dniester River. The assessment of water quality in terms of dissolved oxygen concentration for the Dniester and Prut rivers (during the vegetation period 2022) was distributed as follows:

Dniester River	Spring	Summer	Autumn	Prut River	Spring	Summer	Autumn
O_2, mg/L min	7.42	6.17	4.18	O_2, mg/L min	7.8	7.0	9.5
O_2, mg/L max	10.53	9.86	12.11	O_2, mg/L max	10.0	7.7	10.2
WQC	II - I	III - I	IV - I	WQC	II - I	II	I

CONCLUSIONS

The analysis of the seasonal dynamics of the most important physico-chemical water parameters of the Dniester and Prut rivers made it possible to draw the following conclusions:

– for the Prut River, such dynamics is well pronounced when analysing water temperature and dissolved oxygen concentration. The active water reaction parameter retained low variability (8.15 = 8.60 pH units) in both seasonal and spatial aspects. From the point of view of the functioning of the aquatic ecosystem, the water quality of the Prut River, according to the analyzed parameters, varied between classes I – II.

– for the Dniester River, seasonal dynamics are observed only for the water temperature parameter, except for the Naslavcea-Soroca area, where the impact of the Dniester Hydropower Complex has a temperature pollution character. No seasonal dynamics was observed for pH and oxygen concentration values. Distortion of the seasonal dynamics of these parameters at different locations of the Dniester River, including the Dubossary Reservoirs, is caused by the impact of biogenic and anthropogenic factors. Due to the Dniester good self-purification potential, these impacts are still of a local scale. However, the rigorous regulation of the Dniester runoff by DHPC under conditions of progressive hydrological droughts could reduce this potential to the point of no return. The water quality of the Dniester River, according to the analysed parameters, varied between classes I – IV.

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