

## Spatio-Temporal Analysis of the Ecological State of the Dniester River Transboundary Water

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### ABSTRACT

The ecological state of transboundary water of the Dniester River Basin was analyzed in the context of cross-border cooperation. The major objects of economic activity affecting the state of transboundary water were identified in the Dniester River Basin in Ukraine and Republic of Moldova. It was established that over the years of transboundary cooperation, a decrease in the average annual concentrations of Suspended solids, Nitrites, Chlorides and Sulfates below the maximum permissible values was achieved. The ecological state of the Dniester River transboundary water in time and space was investigated using an integral assessment of the state of the Dniester River water environment. It is recommended to assess the transboundary water ecological state using complex indices. An assessment of the ecological reliability of the Dniester River Basin transboundary water in 2020 was carried out. The research results show that the use of transboundary water of the Dniester River Basin is potentially dangerous. Further cooperation between Ukraine and the Republic of Moldova in the issue of reducing the wastewater containing harmful substances with a synergistic effect, is encouraged.

**Keywords:** the Dniester River, ecological state, transboundary water, complex assessment.

### INTRODUCTION

Water resources (surface, underground and sea) are national wealth, the natural basis for the economic and social well-being of the people of any country. They support livelihoods for people, flora and fauna and are limited and vulnerable, especially when it comes to transboundary water resources and bodies.

According to the current estimations, transboundary surface water bodies (river basins and lakes) occupy almost half of the planet's land surface. About 40% of the world's population lives in the basins of transboundary rivers and lakes that are shared by two or more countries, over 90% of people inhabit the countries that share basins [Basin United Nations]. The intensive use of surface water resources by neighboring coastal countries for the needs of industry, agriculture, energy, transport leads to a change in the ecological state of transboundary basins. Therefore, the water quality monitoring of transboundary water bodies and assessment of

their ability to self-purification potential as well as capability of restoration remain relevant. The degradation of water resources, especially in the context of climate change, still leaves on the agenda the issue of transboundary water cooperation – integrated water resources management (taking into account the economic interests of the development of coastal neighboring countries and the protection of water resources).

The Dniester River basin is located on the territory of the Republic of Poland (0.6% of the catchment area), the Republic of Moldova (26.4%), but most of it (73.0%) is located within Ukraine (Lvivska, Ivano-Frankivska, Chernivetska, Ternopil'ska, Khmelnytska, Vinnytska and Odeska regions) [Website of the Dniester Commission]. The Dniester River Basin is bounded from the west by the Carpathians, from the north-west – by the Sano-Dniester watershed, from the north – by Rostoch, from the south-east – by the Dnieper-Bug firth, from the west – by the Dniester-Prut and Dniester-Black Sea watersheds.

The length of the Dniester River is 1362 km, the catchment area is 68627 km<sup>2</sup>, the average stream gradient is 0.56‰. Ukraine owns the headwater and the mouth stretch of the river with a total length of 705 km. The 220 km section of the river is transboundary for Ukraine and Moldova. The middle and lower parts (437 km long) of the river are located in Moldova. A small section of the Strvyazh River (the headwater of left tributary of the Dniester River) belongs to the Republic of Poland [Website of the Dniester Commission].

The Dniester River is the main source of water for Moldova and, to a large extent, for Ukraine. There are 157 settlements (5 million people) on the territory of the basin within Ukraine, whereas on the territory of Moldova – 43 settlements (2.74 million people). Outside the basin, another 3.5 million people consume the Dniester water [Website of the Dniester Commission]. The western region is the best-resourced of the local runoff of Ukraine, where 200–600 thousand m<sup>3</sup> of water falls per 1 km<sup>2</sup> of territory, and 2–6 thousand m<sup>3</sup> of water per inhabitant [Agricultural Policy Report].

The main factors of the anthropogenic load on surface water resources are both significant water consumption by various sectors of the economy of Ukraine and the Republic of Moldova, and discharges of polluted water. The negative impact on the ecosystem of the river from the source to the mouth is very severe and it is caused by the production activity of oil refineries, chemical plants, and enterprises in the coal, food, forestry, utilities, energy, and agriculture. Most environmentally hazardous enterprises are located in the upper part of the Dniester basin (Lvivska, Ivano-Frankivska regions), where 70% of the runoff is formed. There are powerful enterprises (the largest surface water pollutants of the Dniester River) on the territory of Lvivska and Ivano-Frankivska regions: PSP “Lvivska Coal Company”, PE Mine “Stepova” SE “Lviv Coal”, PSP “Petrochemical of Prykarpattia”, LLC “Carpathian Petrochemical”, Nadvirna oil and gas production division, Oriana Open Joint-Stock Company [Ministry of Environmental Protection and Natural Resources of Ukraine].

The current water consumption of the Dniester River basin water resources by Ukraine is distributed as follows: production needs are 52%, non-refundable use is 25%, municipal services are 17% and agricultural needs are 6% [Transboundary river basin management plan]. The temporal trends of water use in the basin indicate a general

decrease in the use of water, both from surface and underground sources, in all sectors of the economy. The water management situation in the Dniester River Basin demonstrates a different combination of changes in the volume of water intake and the volume of discharge of polluted water over time. For example, for the period 2015–2019, the volume of water intake from the territory of the Khmelnytska region decreased by 22.4%, Vinnytska – by 9.8%, while the volumes of polluted water discharge from the territory of these regions increased by 55.9% and 8.9%, respectively. The water intake from the Dniester River Basin in the Ivano-Frankivska region during the period under review increased by 5.6%, and the discharge of polluted water decreased by 6.9% [Ministry of Environmental Protection and Natural Resources of Ukraine, Dniester Basin Water Resources Management]. Significant amount of water removed from natural sources is still lost when it is transported to water users, as a result of filtration, leaks, and accidents in water supply systems from the point of water intake to the point of its use.

Enterprises of Moldova also have a negative impact on the ecological state of transboundary surface water (metallurgical plant, Ribnita; cement plants in Ribnita and Rezina) [Website of the Dniester Commission]. The total volume of water use in the Republic of Moldova is distributed as follows: utility needs 14% (112.7 million m<sup>3</sup>), industrial needs – 74% (582.8 million m<sup>3</sup>), irrigation – 5% (41.5 million m<sup>3</sup>), agriculture and water supply to rural settlements – 4% (38.2 million m<sup>3</sup>), other needs – 3% (2.2 million m<sup>3</sup>). The annual water intake from the Dniester River Basin by the Republic of Moldova is 754.0 million m<sup>3</sup> (96%). The total volume of discharged water in the country reaches 667.0 million m<sup>3</sup>, of which 661.8 million m<sup>3</sup> (99%) falls on the Dniester River Basin [Website of the Dniester Commission].

Stream flow control significantly affects the ecological state of the Dniester River. 65 reservoirs and 3447 ponds were built on the territory of the river basin. In the middle course of the river, a cascade of channel reservoirs has been built, the largest of which are Dubasari and Dniester reservoirs. Violation of the continuity of the water flow, water intake, and water level fluctuations negatively affect the ecological state of the river.

The agriculture developed on the territory of Ukraine and the Republic of Moldova (crops and vegetables output, horticulture, livestock) leads to the pollution of water bodies with mineral

fertilizers and pesticides. The arable land in the Dniester River Basin reaches 43%. This factor and untreated wastewater have the greatest negative impact on the ecological state of transboundary surface waters [Transboundary river basin management plan].

For the sustainable development of both States, Ukraine and the Republic of Moldova, a Treaty on Cooperation in the Field of Protection and Sustainable Development of the Dniester River Basin was signed on November 29, 2012 in Rome [Agreement between the Cabinet of Ministers of Ukraine and the Government of the Republic of Moldova]. The Treaty seeks to fulfil the commitments undertaken by the Republic of Moldova and Ukraine in 1994 [Convention on the Protection and Use of Transboundary Watercourses and International Lakes, EU Water Framework Directive 2000/60/EC]. At the request of the Government of the Republic of Moldova and the Cabinet of Ministers of Ukraine the GEF / UNDP/ OSCE/ UNECE project “Enabling transboundary co-operation and integrated water resources management in the Dniester River Basin” has been drafted. The purpose of the project was to introduce the mechanisms for the integrated management of water resources in the Dniester River Basin to ensure its sustainable development. According to the GEF project the Dniester Transboundary River Basin Management Plan was approved on June 10, 2019 [Transboundary river basin management plan]. The environmental purposes of the project were to prevent the deterioration of the status of all surface water bodies, protection, improvement and restoration of all water bodies.

## **MATERIALS AND METHODS**

Monitoring of the state of rivers in Ukraine is carried out by observation a network of stations and observation points by state monitoring entities of the Hydrometeorological Service, the Ministry of Environment Protection and Natural Resources, the National Academy of Sciences of Ukraine, the State Agency for Water Resources and the Ministry of Health. The quality of river water is determined according to different methods, while the list of hydrochemical parameters does not always coincide, the number of hydrobiological indicators is limited [Mitryasova et al., 2021 Shakhman et al., 2021]. It is not uncommon for the control results

obtained by different monitoring subjects to differ significantly [Odnorih et al., 2020].

Observations of the surface water quality of the Dniester River Basin on the border areas of Ukraine and the Republic of Moldova are carried out at transboundary points. Three points are located before the entrance of the Dniester water into the territory of the Republic of Moldova (near the village Naslavcea, city Mohyliv-Podil’s’kyi, village Tsikinivka) and four – on the tributaries of the Dniester River on the territory of the Odeska region (Ukraine), after the exit of watercourses from the territory of the Republic of Moldova [National report on the state of the environment in Ukraine in 2018]. At the points of the Dniester River, located on the Ukrainian territory to the border with the Republic of Moldova, the water quality is usually higher than after leaving the Republic of Moldova, on the territory of the Odeska region [National report on the state of the environment in Ukraine in 2018].

The scientists of the Odessa State Environmental University dealt with the problems of water quality assessment in the Dniester River Basin in 2015 [Kolisnyk, 2015]. The water quality of the Dniester River Basin in transboundary areas with the Republic of Moldova, within the Vinnytska region was investigated [Bordova, 2006]. It was found that the surface water of the Dniester River Basin is significantly contaminated. Moreover, the studies on the quality of drinking water in the Dniester River (water intake for 1998–2012) were carried out [Kolisnyk, 2015]. Experts have analyzed the quality of water in the places of sources of centralized drinking water supply by the current standards, and also determined the changes of typical nutrients content in water for years.

Specialists within the GEF Project “Enabling transboundary co-operation and integrated water resources management in the Dniester River Basin” [Transboundary river basin management plan] carried out an assessment of the ecological and chemical status of the surface water of the Dniester River for 2018 in accordance with the Methodology for Attribution of Surface Water Masses to one of the environmental and chemical state classes of the surface water massif [About approval of the Method of assignment of the massif of surface water]. Researchers [Transboundary river basin management plan] noted the risk of not achieving a good ecological status in Ukraine on the transboundary massif of the Dniester River Basin. As for the chemical status, in Ukraine

there is a risk of failing to achieve a good chemical status, while in the Republic of Moldova, on the contrary, there is no such risk.

Monitoring of pollutants in wastewater both in Ukraine and in the Republic of Moldova is carried out only according to the parameters of water users' projects (organic matter and nutrients). The list of basin-specific hazardous substances for the Dniester River Basin is currently not established in Ukraine. In the Republic of Moldova, the list of hazardous substances includes 41 substances [Transboundary river basin management plan]. Heavy metals, pesticides, hydrocarbons are not determined).

The research of the chemical state of surface water in the Dniester River Basin conducted by the Western Region Water Monitoring Laboratory in 2020 shows that the largest amounts of pollutants were detected in the Dniester River at observation posts in the Odeska region (Ukraine) after the river leaves the territory of the Republic of Moldova. A general analysis of laboratory research has established that in 18 surface water massifs of the Dniester River Basin, the content of pollutants exceeds environmental standards, which corresponds to the II class of the ecological state "failure to achieve good" [Chemical state of the Dniester River Basin surface water in 2020].

The methods used in previous research [Transboundary river basin management plan, Chemical state of the Dniester River Basin surface water in 2020] were based for comparing the actual values of water quality indicators with the maximum permissible concentrations without taking into account the potential effect of the total action of pollutants. Therefore, it is relevant to assess the ecological state of transboundary surface water on the basis of complex indices that take into account the effect of the total action of pollutants [Shakhman et al., 2017, Shakhman et al., 2018, Shakhman et al., 2021].

Complex indices are calculated according to hydrochemical parameters and used when it is necessary to trace the spatio-temporal character of the state of rivers in natural and anthropogenic conditions [Shakhman et al., 2021, Bystriantseva et al., 2019]. Such a relatively quick assessment of the ecological state of the surface water of the river enables promptly decision-making on water resources management, which is particularly relevant to cross-border cooperation. A complex assessment of hydrochemical parameters involves the determination of quantitative indicators of the river water state and its qualitative characteristics [Yurasov et al., 2012].

In this study, to assess the ecological state of the Dniester River transboundary surface water, the authors used the method of integral estimation of the aquatic environment state by the pollution coefficient  $\chi$  [Bordova, 2006; Shakhman et al., 2021] and according to the complex indicator CIES [Timchenko, 2002, Shakhman et al., 2021]. The obtained indicators made it possible to move on to assessing environmental reliability *ER* [Timchenko, 2002, Shakhman et al., 2017, 2018, 2021].

The initial information for assessing the ecological state of transboundary surface water of the Dniester River is the analytical monitoring data of surface water (monthly sampling by 12 parameters) by the State Agency for Water Resources of Ukraine for the period 2011–2020 [State Agency of Water Resources of Ukraine]. The observational data was systematized into tables of average annual concentrations of pollutants on gauge stations: 1 – the Dniester River – village Rozvadiv (1191 km from the river mouth); 2 – the Dniester River – city Mohyliv-Podil's'kyi (631 km from the river mouth); 3 – the Dniester River – village Bilyaivka (20 km from the river mouth) for the period 2011–2020.

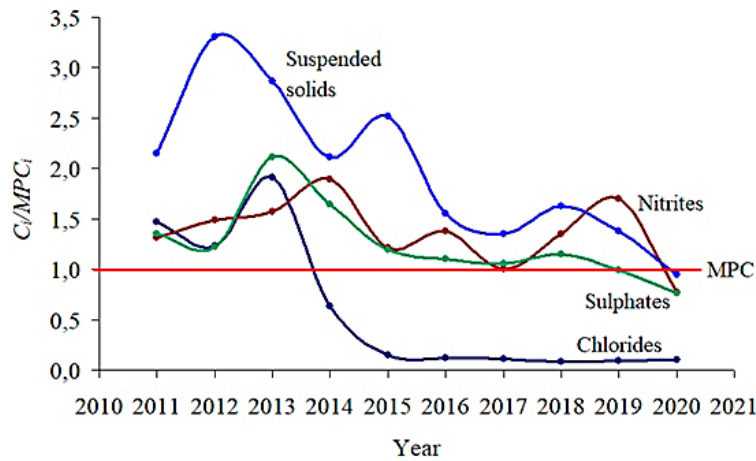
## RESULTS AND DISCUSSIONS

The analysis of changes in the ecological state of the Dniester River in time (for the observation period 2011–2020) and in space (along the river stream) for 2020 using fishery standards that better characterize the change in the state of the river was performed.

A comparative analysis of mean annual concentrations of pollutants for the observation period 2011–2020 for the transboundary point the Dniester River – village Bilyaivka (20 km from the mouth) revealed a significant change in the values of hydrochemical indicators (Figure 1). There is a decrease in the average annual concentrations of the hydrochemical parameters (Suspended solids, Nitrites, Chlorides, Sulphates) lower the maximum permissible concentration (MPC). The positive dynamics of changes in water quality allows us to conclude that the integrated management of water resources in the Republic of Moldova and Ukraine is successful and aims to ensure the sustainable development of water resources in the Dniester River Basin.

However, in the surface water of the lower part of the Dniester River Basin in 2020, the indicator of the toxicological block SAS after the discharge of river water from the territory of the Republic of





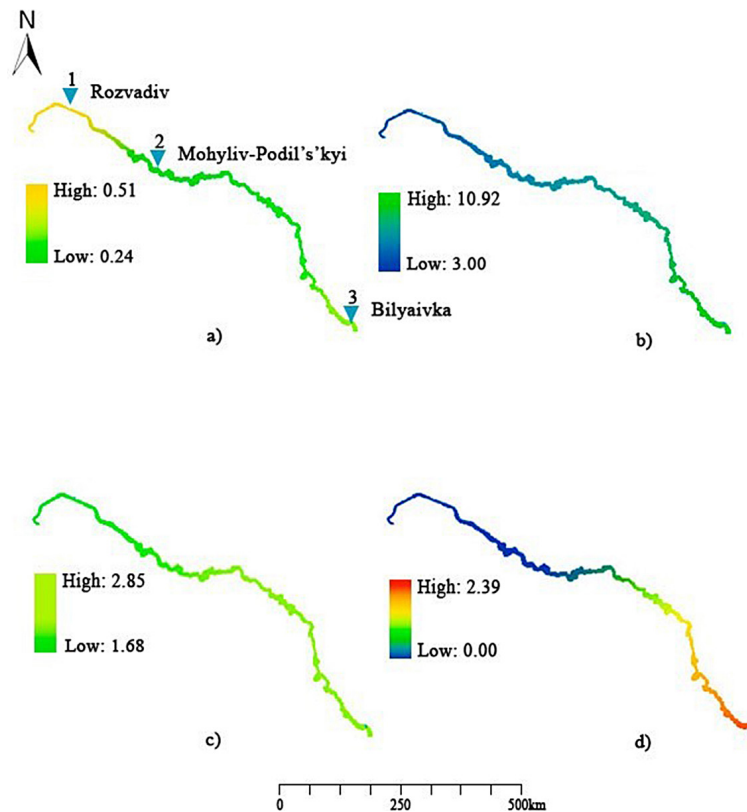
**Figure 1.** Ecological state of the transboundary water of the Dniester River – village Bilyaivka by hydrochemical parameters (Suspended solids, Nitrites, Chlorides, Sulphates) for the observation period 2011–2020

Moldova had a value of 2.39 mg/dm<sup>3</sup> (Figure 2), which exceeds the maximum permissible concentrations of standards for all types of economic use. For the transboundary point the Dniester River – village Bilyaivka the arithmetic mean of SAS for the year has an indicator of class V of the water state (very dirty) [Gritsenko et al., 2012].

In accordance with the methodology [Gritsenko et al., 2012], in 2020, for the analyzed stretch of river (1171 km), the water quality in terms of

average annual values of nutrients (Nitrites, Nitrates and Phosphates), which are necessary for biota, varies from III (moderately contaminated) class up to V (very dirty) class (Figure 3).

For the transboundary section the Dniester River – village Bilyaivka an increase in the concentration of pollutants (Sulphates, Nitrites, Nitrates, Phosphates) is traditionally observed downstream of the river after leaving the territory of the Republic of Moldova (Figure 2, 3).

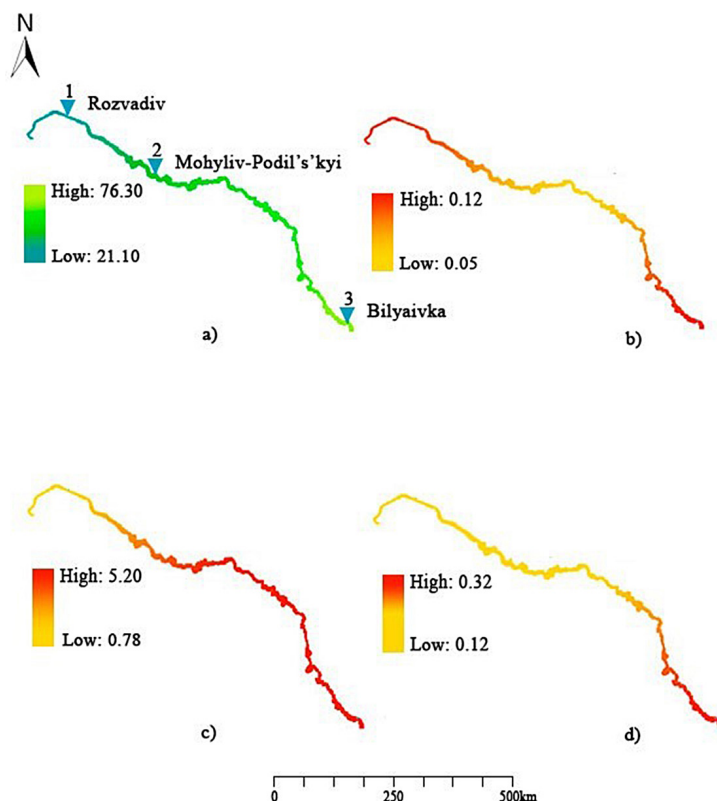


**Figure 2.** Ecological state of the transboundary water of the of the Dniester River: a – Total ammonium, b – Suspended solids; c – BOD5, d – SAS

Hence, the temporal dynamics demonstrates the improvement of the ecological state of the transboundary surface water of the Dniester River, and the spatial assessment shows the presence of unsolved problems, therefore there is a need to refer

to the methods that take into account the synergistic effect of harmful substances for the ecological state assessing [Bordova, 2006; Timchenko, 2002].

At the next stage of the research, an integral assessment of the aquatic environment state,



**Figure 3.** Ecological state of the transboundary water of the of the Dniester River: a – Sulphates, b – Nitrites; c – Nitrates, d – Phosphates

**Table 1.** Integral assessment of ecological state of the transboundary surface water of the Dniester River – village Bilyaivka for 2020

Parameter	$C_i / MPC_i$	With priorities			No priorities		
		rank	$\varphi(i)$	$\varphi(i)C_i / MPC_i$	rank	$\varphi(i)$	$\varphi(i)C_i / MPC_i$
BOD <sub>5</sub>	0.95	1	1.000000	0.95000	2	1.000000	0.95000
Dissolved oxygen	0.65	4	0.500000	0.35200	7	0.109375	0.07109
Suspended solids	0.95	6	0.187500	0.17813	3	0.750000	0.71250
Total ammonium	0.63	2	1.000000	0.63000	8	0.062500	0.03938
Nitrites	0.77	7	0.109375	0.08422	4	0.500000	0.38500
Nitrates	0.07	12	0.005859	0.00041	11	0.010742	0.00075
Chlorides	0.10	10	0.019531	0.00195	9	0.035156	0.00352
Sulphates	0.76	8	0.062500	0.04750	5	0.312500	0.23750
SAS	23.9	5	0.312500	7.46875	1	1.000000	23.9000
COD	0.70	9	0.035156	0.02461	6	0.187500	0.13125
Phosphates	0.09	11	0.010742	0.00097	10	0.019531	0.00176
Petroleum hydro-carbons	0.00	3	0.750000	0.00000	12	0.005859	0.00000
$\Sigma$			3.993163	9.71154		3.993163	26.43275
$\chi = 9.71154/3.993163 = 2.43$ (moderately contaminated)				$\chi = 26.43275/3.993163 = 6.62$ (catastrophically dirty)			

**Table 2.** The summary results of the integral ecological state of the transboundary surface water assessment of the Dniester River – village Bilyaivka for 2011–2020

Year	Estimation of the degree of pollution			
	with priorities		no priorities	
2011	3.58	dirty	10.9	catastrophically dirty
2012	3.02	dirty	8.27	catastrophically dirty
2013	3.33	dirty	10.2	catastrophically dirty
2014	1.53	slightly contaminated	4.20	very dirty
2015	1.64	slightly contaminated	4.81	very dirty
2016	3.35	dirty	6.72	catastrophically dirty
2017	3.82	dirty	11.3	catastrophically dirty
2018	2.25	moderately contaminated	5.83	catastrophically dirty
2019	1.70	slightly contaminated	4.54	very dirty
2020	2.43	moderately contaminated	6.62	catastrophically dirty

**Table 3.** The summary results of the ecological state integral estimation of the transboundary water of the Dniester River – village Bilyaivka for 2020

Estimation of the degree of pollution			
with priorities		no priorities	
the fishery norms			
2.43	moderately contaminated	6.62	catastrophically dirty
drinking norms			
0.93	sufficient clean	2.20	moderately contaminated
cultural and recreational norms			
0.75	sufficient clean	1.63	slightly contaminated

using the pollution coefficient  $\chi$ , was carried out. An example of a calculation for the Dniester River – village Bilyaivka in accordance with the fishery standards is given in Table 1.

The research results of pollution degree of the Dniester River – village Bilyaivka for 2011–2020, based on fishery needs are presented in Table 2.

The research results of pollution degree of the Dniester River – village Bilyaivka for 2020 based on norms for all types of economic use are shown in Table 3.

The next research stage involved estimation of the ecological state of the Dniester River transboundary water for 2020 based on complex indices *CIES*. Sustainability of the river was also calculated. The ecological state estimation of the Dniester River based on *CIES* at the Dniester River – village Bilyaivka transboundary point for the year 2020 is given in Table 4.

The research results of the ecological state estimation of the transboundary water along the Dniester River for the year 2020 are shown in Table 5.

The ecological state of the Dniester River in the upper course of the river is assessed as unsteady, in the middle course of the river (transboundary point near the border with the Republic of Moldova) – steady with signs of unsteady. An unsteady ecological state is also observed after the discharge of river water from the territory of the Republic of Moldova in the lower section of the Dniester River. The minimum and mean coefficients testify to the deterioration of lower course of the river water quality. The obtained values agreed with the calculated by coefficient  $\chi$  and confirm the need to introduce measures for the rational use of transboundary water in the process of managing the transboundary Dniester River Basin.

A slight improvement of the ecological state of the river can be explained by increase river runoff and the possible accumulation of pollutants in the Dniester Reservoir (length is 194 km), upstream city Mohyliv-Podil’s’kyi.

The results of calculating the environmental reliability of the Dniester River in space ( $ER = 0.24$ ) indicate a low potential for self-purification and self-restoration.

The results of assessing the ecological state of transboundary surface water of the Dniester River (Tables 2, 3, 5) make it possible to recommend to the Commission for the Protection and Sustainable Development of the Dniester River, established by the Treaty between the Cabinet of Ministers of Ukraine and the Government of the Republic of Moldova [Website of the Dniester

**Table 4.** Estimation of the ecological state of the transboundary water for 2020 for fishery norms for the Dniester River – village Bilyaivka

LIH	Parameter	$C_i$	MPC	$MPC - C_i$	IES	CIES
General health	Suspended solids	19.0	20.0	1.0	0.05	
	BOD <sub>5</sub>	2.85	3.0	0.15	0.05	
	Dissolved oxygen	9.29	>6.0	3.29	0.548	
$\Sigma$					0.648	0.216
Toxicological	Total ammonium	0.32	0.5	–	0.64	
	Nitrites	0.06	0.08	–	0.75	
	SAS	2.39	0.1	–	4.78	
$\Sigma$					6.17	–5.17
Sanitary-toxicological	Chlorides	29.6	300	–	0.099	
	Sulphates	76.3	100	–	0.763	
	Nitrates	2.69	40.0	–	0.067	
	Phosphates	0.32	3.5	–	0.091	
$\Sigma$					1.02	–0.02
Fishery	Petroleum hydro-carbons	–	0.05	–	–	–
$CIES_{mean} = (0.216 - 5.17 - 0.02) / 3 = -1.66$ , $CIES_{min} = -5.17$ (the ecological state of the object is unsteady)						

**Table 5.** Estimation of Ecological State of the Dniester River transboundary water along the river stream of the year 2020

Gauge station	Complex index of the ecological state (CIES)	
	min	mean
the Dniester River – village Rozvadiv	–1.49	–0.11
	unsteady	
the Dniester River – city Mohyliv-Podil's'kyi	–0.06	0.20
	steady with signs of unsteady	
the Dniester River – village Bilyaivka	–5.17	–1.66
	unsteady	

Commission], to develop and implement additional environmental protection measures. These activities should be aimed to reduce inputs of hazardous substances with synergistic effect to water of the Dniester River Basin (hazard class 2 with health toxicological limit value, hazard classes 3 and 4) [Timchenko, 2002].

It is important according to the Trialogue Model [Guidance on Water and Climate Adaptation] to continue the effective engagement between government, science and society. Moreover, under modern conditions the relevance of the decision-making process for the management of transboundary surface water of the Dniester

River is strengthened by an additional factor of influence on natural resources – climate change. The estimated increase in the average annual air temperature in the basin of the Dniester River in 2021 will be 1.1°C, which will also affect the ecological state of the transboundary surface water of the Dniester River.

The data on the current ecological state of transboundary surface water of the Dniester River and the possible change in water quality in the future will allow the parties to cooperate to overcome the difficult situations related to the lack of freshwater, which can be enhanced by the deterioration of surface water quality and climate change.



## CONCLUSIONS

The ecological state assessment of trans-boundary surface waters of the Dniester river basin in time and space was conducted. After the years of cross-border cooperation between the Republic of Moldova and Ukraine in the fields of environment and sustainable development of the Dniester River Basin, the countries achieved a decrease in the average annual concentrations of the hydrochemical parameters (Suspended solids, Nitrites, Chlorides, Sulphates) below the maximum permissible concentrations. However, at the gauge stations of the Dniester River, located on the Ukrainian territory to the border with the Republic of Moldova, the water quality is usually higher than after leaving the Republic of Moldova. For the transboundary point the Dniester River – village Bilyaivka in 2020 Synthetic surfactants exceeded the maximum permissible concentrations of standards for all water users (fishery, drinking, cultural and recreational) and corresponded to V (very dirty) water quality class.

The results of the spatial-temporal study of the ecological state of the transboundary water of the Dniester River in 2020 according to integrated indicators: by the pollution coefficient – “catastrophically dirty”; CIES – “ecological state of a water body is unsteady”. Ecological sustainability is below 0.8 indicating a low potential for self-purification potential and capability of restoration of the river. Therefore, the use of the Dniester River Basin transboundary water is potentially dangerous.

The research results can be used for the development and/or adjustment of transboundary agreements between the riparian countries (Republic of Moldova and Ukraine) in the periodic review of water consumption standards with considering of the ecological state of the Dniester River. In order to achieve and maintain good quality of the Dniester River Basin transboundary surface water, Ukraine and the Republic of Moldova, individually or jointly, should take the measures to prevent, limit, reduce or eliminate pollution of the hydroecosystem.

## REFERENCES

1. About approval of the Method of assignment of the massif of surface water to one of classes of ecological and chemical states of the massif of surface water, and also assignment of artificial or essentially

changed massif of surface water to one of classes of ecological potential of artificial or essentially changed massif of surface water. <https://zakon.rada.gov.ua/laws/show/z0127-19#Text> (access: 18.05.2021). (in Ukrainian).

2. Agreement between the Cabinet of Ministers of Ukraine and the Government of the Republic of Moldova on Cooperation in the Field of Protection and Sustainable Development of the Dniester River Basin. [https://unece.org/fileadmin/DAM/env/water/centralasia/Dniester\\_Treaty\\_printed\\_rus-UA.pdf](https://unece.org/fileadmin/DAM/env/water/centralasia/Dniester_Treaty_printed_rus-UA.pdf) (access: 06.05.2021). (In Russian).
3. Agricultural Policy Report “Impact of Climate Change on Wheat Production in Ukraine” (APD/APR/02/2016). [https://apd-ukraine.de/images/APD\\_APR\\_05-2016\\_impact\\_on\\_wheat\\_ukr\\_fin.pdf](https://apd-ukraine.de/images/APD_APR_05-2016_impact_on_wheat_ukr_fin.pdf) (access: 23.04.2021). (in Ukrainian).
4. Basin United Nations. <https://www.unwater.org/water-facts/> (access: 28.04.2021).
5. Bordova V.G. (ed.). 2006. Hygiene and ecology. Vinnytsia: New Book. 720 (in Ukrainian).
6. Bystriantseva A., Shakhman I., Bystriantsev M. 2019. Spatio-temporal representation of the ecological state of the surface waters of the Lower Section of the Dnieper River using GIS technologies. Proc. ICTERI 2019, I (2387).
7. Chemical state of the Dniester River Basin surface water in 2020. <https://vodaif.gov.ua/wp-content/uploads/2021/02/PIDSUMOK-za-2020-rik-laboratoriya.pdf> (access: 18.05.2021). (in Ukrainian).
8. Convention on the Protection and Use of Transboundary Watercourses and International Lakes. [https://www.un.org/ru/documents/decl\\_conv/conventions/watercourses\\_lakes.shtml](https://www.un.org/ru/documents/decl_conv/conventions/watercourses_lakes.shtml) (access: 08.05.2021). (In Russian).
9. Dniester Basin Water Resources Management. <https://vodaif.gov.ua> (access: 23.04.2021). (in Ukrainian).
10. EU Water Framework Directive 2000/60/EC. [https://ec.europa.eu/environment/water/water-framework/index\\_en.html](https://ec.europa.eu/environment/water/water-framework/index_en.html) (access: 09.05.2021).
11. Gritsenko A.V., Vasenko O.G., Vernichenko G.A. et al. 2012. Methodology of ecological assessment of surface water quality by appropriate categories. Kh. UkrNIEP. (in Ukrainian).
12. Guidance on Water and Climate Adaption. UNECE: Sustainable development goals. <https://www.unece.org/index.php?id=11658> (access: 19.06.2021).
13. Kolisnyk A.V. 2015. Current situation of water quality Dniester River basin in transboundary areas. Ukrainian Hydrometeorological Journal, 16, 202–208. (in Ukrainian).
14. Ministry of Environmental Protection and Natural Resources of Ukraine. <https://mepr.gov.ua/news/35913.html> (access: 21.04.2021). (in Ukrainian).

15. Mission “Save the rivers in Ukraine”: let’s start with the Dniester River. <https://ns-plus.com.ua/2019/02/12/misiya-vryatuvaty-richky-v-ukrayini-pochynayemo-z-dnistra/> (access: 19.06.2021). (in Ukrainian).
16. Mitryasova O., Pohrebennyk V., Salamon I., Oleksiuk A., Mats A. 2021. Temporal Patterns of Quality Surface Water Changes. *Journal of Ecological Engineering*, 22(4), 283–295.
17. National report on the state of the environment in Ukraine in 2018. Kyiv, 2019. 483. (in Ukrainian).
18. Odnorih Z., Manko R., Malovanyy M., Soloviy Kh. 2020. Results of surface water quality monitoring of the Western Bug River basin in Lviv region. *Journal of Ecological Engineering*, 21(3), 18–26.
19. Romanchuk M.Y., Tkach K.S., Polischuk A.A., Kolisnyk A.V. 2015. Assessment of water quality of the Dniester River-water intake for 1998–2012. For typical water years.
20. Shakhman I.A., Bystriantseva A.N. 2017. Assessment of Ecological State and Ecological Reliability of the Lower Section of the Ingulets River. *Hydrobiological Journal. USA*. 53(5), 103–109. DOI: 10.1615/HydrobJ.v53.i5.110.
21. Shakhman, I.A., Bystriantseva, A.N. 2018. Assessment of ecological state and ecological reliability of the Lower section of the Dnieper River. Proc. 18th International Multidisciplinary scientific GeoConference SGEM, 113–119.
22. Shakhman I., Bystriantseva A. 2021. Water Quality Assessment of the Surface Water of the Southern Bug River Basin by Complex Indices. *Journal of Ecological Engineering*, 22(1), 195–205.
23. State Agency of Water Resources of Ukraine. <http://monitoring.davr.gov.ua/Reporting/ViewReports/ViewReport?id=393> (access: 21.04.2021). (in Ukrainian).
24. Timchenko Z.V. 2002. Water resources and the ecological state of the small rivers of the Crimea. Simferopol: Dolya, 152 (in Ukrainian).
25. Transboundary river basin management plan. [https://dniester-commission.com/wp-content/uploads/2019/07/Dniester\\_TDA\\_July2019.pdf](https://dniester-commission.com/wp-content/uploads/2019/07/Dniester_TDA_July2019.pdf) (access: 06.05.2021). (In Russian).
26. Yurasov S.M., Safranov T.A., Chugai A.V. 2012. Assessment of natural water quality. Odessa: Ecology. 168 (in Ukrainian).
27. Website of the Dniester Commission. <https://dniester-commission.com/bassejn-reki-dnestr/region/> (access: 21.04.2021). (In Russian).