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Estimation of quality of surface water of Dniester river basin within Lviv and Khmelnytsk regions

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The problem of deterioration of the ecological condition of river basins of Ukraine is extremely important. Particular attention is paid to transboundary rivers, which include the Dniester River. The article describes the physical and geographical conditions of the Dniester basin, analyzes the scale of water use and discharge of return water in to the surface reservoirs in the basin. The use of water resources of the basin by different sectors of the economy is studied. 50% in Lviv region and 72% in Khmelnytsk region of abstracted water is used for commercial and drinking purposes, respectively 30% and 25% - for production. The largest sources of river basin pollution within Lviv and Khmelnytsk regions are considered. The main pollutants of surface water bodies in Lviv region in terms of the amount of effluents are enterprises of housing and communal services, enterprises of heat and power, chemical and petrochemical, machine-building and food industries. Among the enterprises of Khmelnytsk region, the largest volumes of wastewater discharges are carried out by the enterprises of heat and power, housing and communal services, food and construction industries. It is established that the major factors influencing the deterioration of surface in the river basin are disposals of sewage. The ecological danger from hydrosphere pollution in the Dniester basin has been assessed on the basis of pollutant concentrations. The results of monitoring water pollution in the river Dniester basin testified that the main pollutants that exceed the level compared to the maximum permissible concentration are nitrites, and for its tributaries river Lug and river Smotrych also ammonium salt, nitrates, sulfates and phosphates. As a result of a comprehensive assessment of the water quality of the river basin, the characteristics assigned to them are weakly and moderately polluted. Except for pollution of water objects, the urgent problem demanding the solution is the acting landscape structure in the basin of river Dniester. The disturbed structure of territories is the result of excessive agricultural land use and reduction of the area of natural lands. We came up with the priority tasks are to minimize the discharges of polluted return water into the water bodies, to improve the economic mechanism of water use and implement of water protection measures, to optimize the landscape-ecological structure of the territory, in particular increase the areas of nature reserve fund.

Key words: surface water, the Dniester River basin, tributary, water service, pollution, water quality, landscape structure.

Introduction

Solving the environmental problems of Ukraine's water resources requires a comprehensive solution to many issues, which require the participation of all sectors of the economy of Ukraine, that is, all directions of water consumption and water use. These issues are addressed taking into account the characteristics of the main large and small rivers in their basins (Paraniak et al., 2014; Tomiltseva et al., 2017; Grynevych et al., 2018; Paranjak et al., 2019; Rudenko et al., 2019; Honcharova et al., 2019; Borshch et al., 2020).

Water resources in natural conditions are formed by the basin principle, when rivers are a dynamic system subject to zonal laws (Iatsyk, 2004). According to Article 13 of the Water Code of Ukraine, public administration in the field of use and protection of water and reproduction of water resources is carried out on a basin basis. on the basis of state, interstate and regional programs of water use and protection and reproduction of water resources. A reservoir basin (rivers, reservoirs, lakes, canals, ponds, swamps) should be considered as objects of ecosystem management. Economic activity in all directions is carried out throughout the basin of the reservoir. As for the territories of administrative (regional, district) subordination, it is only a water management section, that is, part of the basin of which it consists.

Problems of basin management of natural resources, ecological assessment of the territory and optimization of nature management were dealt with by I.P. Kovalchuk, R.S. Chalov, M.R. Pytulyak, A.B. Colisnyk and many other scientists. In particular, the study of the hydrochemical regime and surface water quality of the Dniester basin is devoted to the monograph of V.K. Khilchevskyj, O.M. Gonchar, M.R. Zabokrytska and others. (2013); geoecological searches of river-basin systems, in particular the systems of the upper Dniester monograph O.V. Pylypovych and I.P. Kovalchuk (2017).

Ecological and hydrochemical research is an important tool for ecological monitoring of natural waters, especially in modern conditions of intensive nature management (Kalyn et al., 2011). A comprehensive research of the problems of nature

management is especially relevant for regions with a high degree of economic development of natural resources, high intensity of their exploitation. The Dniester basin belongs to such areas. Therefore, it is important to search the geoecological condition of both the Dniester River and its tributaries to solve problems of rational and environmentally reasonable water use, environmental monitoring.

Materials and Methods

The network of hydrochemical monitoring of river waters of the Dniester basin has 40 observation points. We focused on water quality assessment within two water management sections of the basin - Lviv and Khmelnytsk regions (upper and middle part of the basin). Quality condition of surface waters of the Dniester river basin was searched in 4 sections, 2 of which are located mainly along the riverbed (above the town of Rozdil, Lviv region and near the village of Tsviklivtsi, Kamyanets-Podilsk district, Khmelnytsk region before the confluence of the Smotrych river) and 2 - in the tributaries: Luh river, below the town of Khodoriv (Lviv region) and Smotrych river, below the village Tsybulivka (Khmelnytsk region). Sampling was carried out in April-May 2019 and 2020. Laboratory analysis of water samples was performed according to standard methods. Pollution researches were conducted according to the data assigned to the MPC.

For the integrated assessment of water quality of the Dniester River and its tributaries, the method of calculating the pollution coefficient (K_3) was used (Metodyka rozrakhunku..., 2003). According to this technique for the most critical indicators of water quality Cu (i = 1, 2,..., n), which have the highest values or exceed their maximum permissible concentrations (MPC), perform the calculation by the formula:

$$K_3 = \frac{1}{n} \sum_{i=1}^{n} \frac{C_i}{C_{f_i}}$$

where K_3 is the value of the coefficient of the pollution; C_i - the actual value of the concentration of the i-th component; C_{f_i} - the value of the MPC of the i-th component n - the total number of measured indicators.

According to the value of the calculated K_3, the water, the quality of which is analyzed, belongs to one of the five classes of water quality.

Results and Discussion

The Dniester is a transboundary river, its basin occupies the southwestern part of Ukraine and the eastern part of Moldova. between Ukraine and the Republic of Moldova. It is the second longest river in Ukraine and the ninth in Europe. From the sources to the town of Staryj Sambir the Dniester flows among the Carpathian mountains, further - on the plain territory of Ukraine and Moldova. From the village Kozlov (Mohyliv-Podilskyi district, Vinnytsia region, Ukraine) to the village of Nimeriuki (Sorotsjc district, Moldova) on the Dniester is the state border between Ukraine and Moldova. Then the river flows through the territory of Moldova. From the village Purkara (Stefhan Vodskyj district, Moldova) to the village of Palanka on the Dniester is the border between the two states. Below the village Palanka Dniester flows through the territory of Ukraine (Afanasiev-Chuzhbynskyi, 2016).

The length of the river is 1362 km. The catchment area of the Dniester basin is 72.9 thousand km^2, of which 53.49 thousand km^2 or 73% are located within Ukraine. In Ukraine, the basin covers large parts (from 13 to 80%) of the territory of seven regions (Lviv, Ivano-Frankivsk, Chernivtsi, Ternopil, Khmelnytsk, Vinnytsia and Odessa). The pool has the shape of a very elongated, curved in the middle of an oval about 700 km long with an average width of 120 km. Heights in the mountainous part of the basin reach 1000-1800 m.

The main feature of the hydrographic network of the Dniester basin is the absence of significant tributaries. There are 14,886 rivers in the Dniester basin with an average river network density of 0.65 km/km^2.

The pool is home to about seven million people, more than five of them in Ukraine. There are 62 cities within Ukraine (including the regional centers of Lviv, Ivano-Frankivsk, Ternopil and the industrial cities of Drohobych, Boryslav, Stryj, Kalush, Stebnyk) and 95 urban-type settlements, and within Moldova - 2 municipalities and 41 cities (including Kyshyniv, Beltsi, Soroca, Orhei, Rybnitsa, Dubossary, Tiraspol, Bendery).

Many settlements are provided with drinking water from the Dniester or its tributaries. In the Lviv region, the water intake in the Dniester basin in 2019 amounted to 108.94 million m^3, while in the Khmelnytsk region - only 17.53. Also in the Lviv region a significant number of water users - 373, which is the largest of all regions within the Dniester basin (Table 1).

Table 1. Water use by water consumers in the Dniester river basin

superficial	Water uptake, million m^3 underground	general	Water use limit	Number of reporting water users
	Lviv region			
20.80	88.14	108.94	440.0	373
	Khmelnytsk region			
10.89	6.648	17.53	25.62	92
	Total for the pool			
320.1	137.9	457.92	843.339	1173

In the structure of economic sectors, the use of water resources of the basin also has its differences. Diagrams of water use in the Dniester basin are presented in fig.1. In Lviv region, half of the abstracted water is used for economical and drinking purposes, a third - for production, and the rest - for agricultural purposes. In Khmelnytsk region, 72% of the abstracted water is used for economical and drinking needs, a quarter - for production and a small part for agriculture, including irrigation.
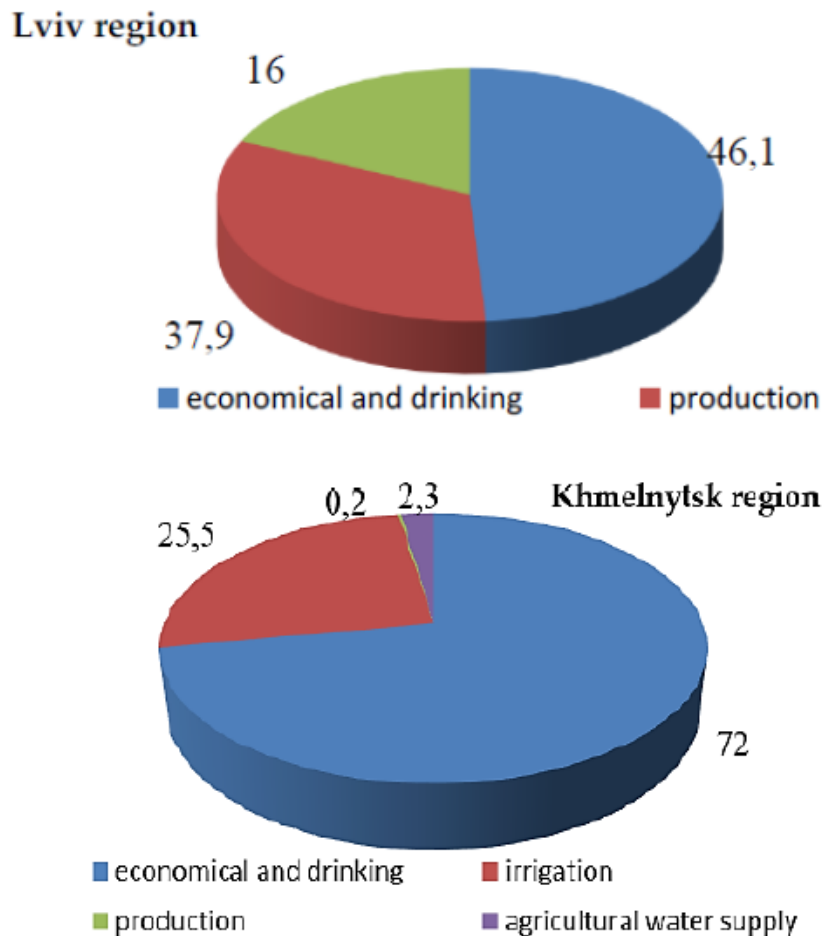

Fig. 1. Diagrams of water use in the Dniester basin

According to the amount of used water, wastewater is discharged into the Dniester and its tributaries. In 2019, 29.8 million m^3 of wastewater in the Lviv region and 7.7 million m^3 in the Khmelnytsk region were discharged into the water objects of the basin. Regarding the sources of pollutants discharged into the Dniester river basin, their number and density within the basin is much higher in the Lviv region. In addition, increasing number of sewage is discharged here. The largest ecologically dangerous enterprises - pollutants the Dniester basin in Lviv region include 13, and in Khmelnytsk - 4.

The main polluters of surface water reservoirs in the Lviv region in terms of the number of effluents are housing and communal services enterprises, however, in terms of the amount of polluted effluents, including without purification, the enterprises of heat power, chemical and petrochemical, machine-building and food industries dominate. Among the enterprises of Khmelnytsk region, the largest volumes of wastewater discharges are carried out by the enterprises of heat energy, housing and communal services, food and construction industries.

In fig. 2 a comparative characteristic of the discharge of return water into surface water objects within the searched areas is given. The amount of return water discharged into the surface water objects of the Dniester basin within the Lviv region is 31.6%, 48.9% and 19.5% of normatively clean, normatively cleaned and uncleaned/insufficiently cleaned waters from each category of discharges in the region. Within the Khmelnytsk region - 15.7%, 10.7% and 31.2%, respectively.

It should be noted that the total volume of return water discharge in Lviv region is 5 times higher than in Khmelnytsk region. However, water supply per capita in Lviv region. is 2.21, Khmelnytsk – 7.78 thousand m^3/year. This indicates a much higher anthropogenic load of water objects in the Lviv region.

Surface waters best reflect the intensity of human economic activity and are a qualitative indicator of the state of the environment. In fig. 3-6 the results of research of selected water samples in cross-sections of the Dniester and its tributaries are given. In general, water indicators in the cross-sections near the town Rozdil and the village Tsviklivtsi of Kamyanets-Podilsk district met the standards, except for BSK_5 in the second cross-sections in 2020.

The excess of nitrite content in water samples of the Dniester River was also found to be 1.4 and 1.35 times (2019) respectively and 1.1 and 1.5 times (2020) and nitrates in the cross-sections near the village Tsviklivtsi of Kamyanets-Podilsk district 1.1 times during the research.

As for the other indicators, they were not detected in the water samples of the Dniester River, except for total iron in the cross-section near the town of Rozdil, but such values are typical for the entire upper part of the Dniester, and probably due to the

chemical composition of the rocks of this territory. Here the rocks are mainly presented with heavy carbonate-free loams, have a significantly heavier particle size distribution, due to the high content of silt and fine-grained particles, are denser and less porous, more gleyed and iron, often contain iron crusts, iron and iron-manganese nodules (Hnatiuk, 2017).
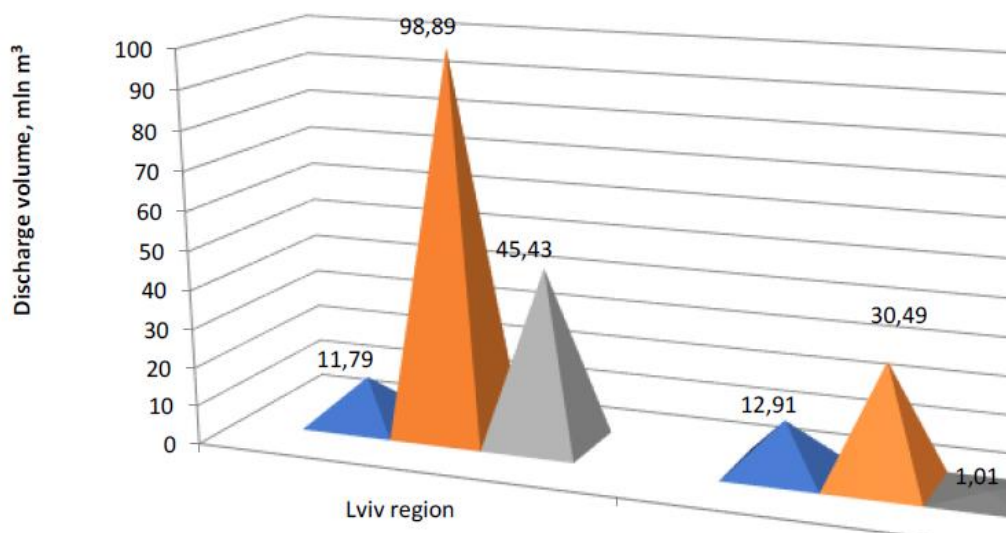

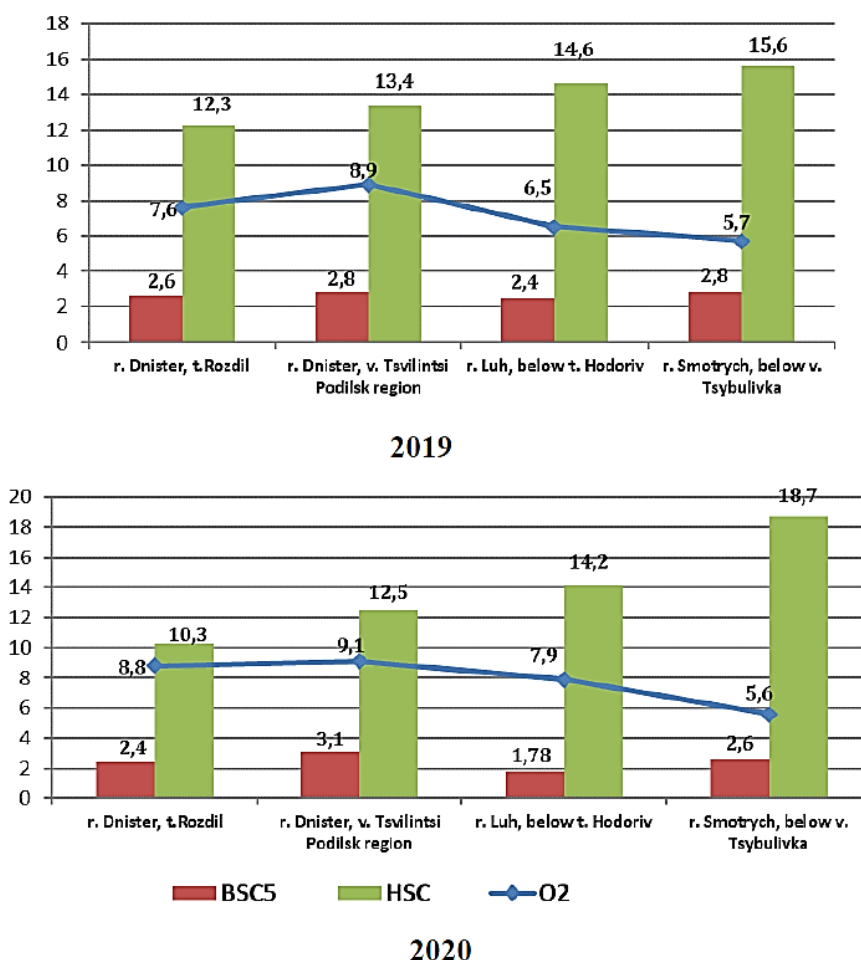**Fig. 2.** Discharge of return waters into surface water objects

Fig. 3-4. The amount of dissolved oxygen, the values of HSC and BSC₅ in the water of the Dniester River and its tributaries, mgO$_2$/dm$_3$

In the water of the tributaries of the Dniester River there is an excess of the maximum allowable values of surface water quality indicators: HSC (Smotrych River, 1.25 times), sulfates (Smotrych River, 1.1 times), salt ammonium (Lug River 2.3 times and Smotrych River 1.4 times), nitrates (Lug River 1.8 times and Smotrych River 1.4 times), nitrites (3.5 and 8.4 times in all samples, respectively), phosphates (Lug River 4 times and Smotrych River 11 times) and total iron (1.1 and 1.3 times, respectively).

The hierarchy of the water system is manifested in the fact that the catchment basin of the river of the highest order contains the basins of rivers of lower order. Accordingly, the geoecological state of the entire river system is determined by the state of all lower-order basins and reflects the interaction between the system itself and the external environment (Pylypovoch & Kovalchuk, 2017; Melnychuk & Protsiv, 2019). The enterprises of "Khodoriv Meat-packing Plant", Ltd "Vinal-Agro", Ltd "Lemberg-Agro" have a direct influence on the condition of the Lug River, as well as utilities that discharge wastewater - SE "Vodokanal" Khodoriv. The towns of Gorodok and Kamyanets-Podilsk and 30 rural settlements are located on the banks of the Smotrych River.
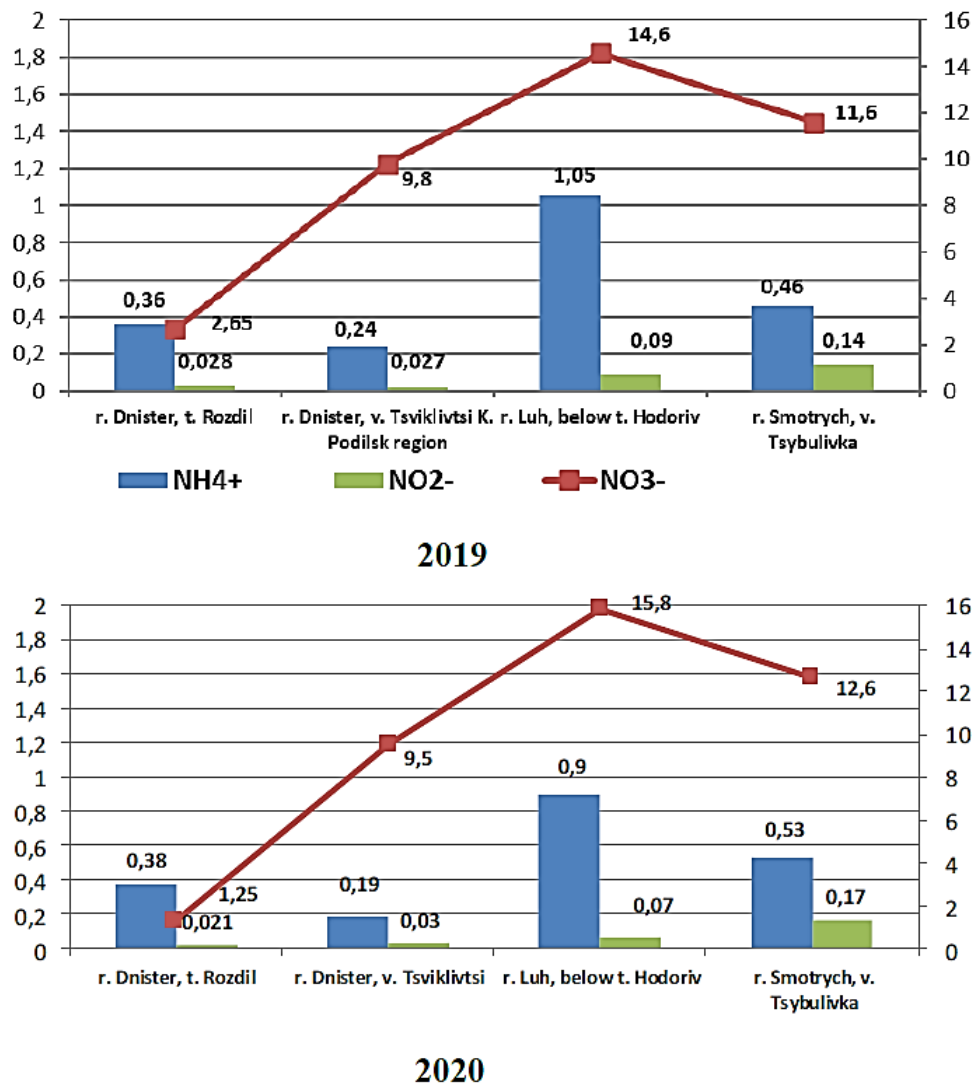

2019

2020

Fig. 5-6. Concentration of salt ammonium, nitrites and nitrates in the water of the Dniester River and its tributaries, mg/dm^3

In order to comprehensively assess the ecological status of surface water objects, the pollution factor was calculated. The water of the Dniester River in the studied areas was characterized as slightly polluted. The water of the Luh River, a tributary of the Dniester in the Lviv region, was also slightly polluted, and the water of the Smotrych River, a tributary of the Dniester in the Khmelnytsk region, is moderately polluted.

Table 2. K_3 for the Dniester River and its tributaries

Name of control targets	Indexes	
	Value K_3	Characteristic K_3
Lviv region		
river Dniester, Rozdil	1.26	Slightly polluted
river Luh, lower, Hodoriv	1.86	Slightly polluted
Khmelnytsk region		
river Dniester, village Tsviklivtsi	1.07	Slightly polluted
river Smotrych, lower, village Tsybulivka	3.09	Moderately polluted

The ecological condition of rivers is characterized by increased anthropogenic loading, due to the high percentage of areas of basins occupied by unstable elements of the landscape, violation of management standards and requires urgent environmental

measures aimed at optimizing the landscape structure of the catchment area (Bovsunivska, 2014; Krainiukov & Timchenko, 2016). A number of protected areas have been created along the Dniester. In the Lviv region it is the Regional Landscape Park "Verhnjodniester Beskids", Khmelnytsk – "Podilsk Tovtry" National Nature Park. It is important that the water area of the river is also included in the protection zone. Interference in the functioning of the river system, even in areas adjacent to protected areas, is dangerous for the functioning of protected ecosystems (Khilchevskyi et al., 2013).

Today, a large part of the Dniester river basin is plowed - agricultural land occupies about 70% of its area. In addition to changing natural landscapes, this leads to degradation and erosion of soils and to pollution of surface and groundwater by washout products, including nitrogen and phosphorus compounds, pesticides and suspended solids. The ratio between natural and anthropogenic landscapes of Lviv region within the Dniester basin is 26%: 74%, and Khmelnytsky region - 29%: 71%, which indicates a severely disturbed structure of territories.

Conclusions

The main cause of water pollution in the Dniester River is the discharge of a significant amount of uncleaned and insufficiently cleaned wastewater from point and planar sources of pollution, as well as tributaries. As a result of a comprehensive assessment of the water quality of the river basin, the characteristics assigned to them are weakly and moderately polluted.

To create a favorable regime of water resources of the Dniester basin and to prevent their pollution, it is necessary to implement the construction and reconstruction of water supply systems, sewerage and cleaned facilities, and solid waste landfills; to minimize discharges of polluted return water into water objects; to improve the economic mechanism of water use and introduce of water-saving technologies; to organize the water protection zones; to optimize the landscape and ecological structure of the territory; to perform GIS monitoring of water objects and water use.

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