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River systems of the Volyn region: status, problems, and ways of preservation

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ABSTRACT

Introduction. River systems of the Volyn region are important components of the natural environment, ensuring the functioning of aquatic ecosystems, the formation of the hydrological regime of the territory, and the satisfaction of the needs of the population and the economy in water resources. Under current climate change and increasing anthropogenic pressure, they are undergoing significant transformations, manifested in changes in the hydrological regime, deterioration of water quality, and degradation of natural ecosystems. This necessitates their comprehensive ecological assessment, identification of key influencing factors, and development of effective approaches to water resource conservation and rational use.

Purpose. The aim of the study is a comprehensive assessment of the ecological status of river systems in the Volyn region under current environmental conditions, identification of the main threats to aquatic ecosystems, analysis of the level of anthropogenic load, and substantiation of scientific and practical approaches to their conservation and sustainable use.

Relevance. The relevance of the study is driven by the increasing anthropogenic pressure on small river basins associated with agricultural development, land reclamation, urbanization, and other economic activities. This leads to disruption of natural runoff formation processes, degradation of aquatic ecosystems, loss of biodiversity, and deterioration of water quality. These problems are particularly acute in the Polissya region and the forest-steppe zone of Volyn.

Methods. The study applies a set of general scientific and specialized methods, including comparative geographical analysis to identify spatial differences, mathematical statistics for data processing and interpretation, cartographic analysis for mapping basin structure, field observations for primary data collection, and synthesis. The research is based on integrated methodological approaches, including genetic, historical, systemic, and basin-based frameworks.

Results. The study provides a systematic analysis of the current state of river basin systems in Volyn and identifies the types and intensity of anthropogenic pressure on low-flow watercourses. Both qualitative and quantitative indicators of anthropogenic impact were established, and a system of indices for assessing the degree of environmental transformation was developed. An evaluation of the ecological status of water bodies was conducted, revealing key trends in their changes.

Novelty. The scientific novelty lies in the development and improvement of methodological approaches for analyzing and assessing anthropogenic transformations in small river catchments, enabling more accurate determination of ecological change levels and forecasting the further development of river systems.

Practical significance. The results can be used to improve water resource monitoring systems, develop environmental protection measures, enhance water management

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efficiency, and ensure the rational use of water resources in various sectors of the economy.

Discussion. The study analyzes natural, climatic, and physical-geographical factors influencing river runoff formation, assesses the impact of key economic sectors on aquatic ecosystems, and identifies major degradation drivers. A set of measures aimed at reducing anthropogenic pressure, improving water quality, and restoring the natural functioning of river systems is proposed

Introduction

Water resources, particularly rivers, are among the most important natural resources. They are easily accessible and widely used as sources of water supply and recreation for the population. Recently, environmental problems have been exacerbated by intensive water pollution, reduced water availability, river regulation, and the degradation of coastal strips and wetland ecosystems. Such changes disrupt the natural functions of rivers, pose risks to public health, and hinder the sustainable development of the region, necessitating a comprehensive analysis of Volyn's water assets, the identification of threats, and the development of an effective strategy for their preservation.

River waters are highly sensitive to changes occurring in the atmosphere, lithosphere, and Earth's surface due to economic activity. River waters and their condition are affected by the construction of reservoirs, residential and industrial buildings, and the introduction of central water consumption in cities and towns. The modern world lives in conditions of constant change, which is a consequence of the interaction between economic activity and the natural environment. Environmental crises affect both the global and regional levels. Hydrological problems are among the most pressing issues in natural resource management. River water resources are a key element of natural resource use, influencing the nature of economic activity and often limiting it. Groundwater distribution in Ukraine varies significantly, mainly due to natural conditions. The use of river water leads to changes in the hydrological regime and deterioration of water quality in natural water bodies. In addition, in conditions of global warming, the consumption of clean fresh water is increasing. Therefore, it is becoming increasingly important to study the current conditions of river water resources formation, water quality, and water use issues. The topic of the work is consistent with the priorities of scientific and technical development in the conditions of martial law in Ukraine (direction 5 "rational use of natural resources"), approved by Law of Ukraine No. 5534-IX of 21.12. 2023; the Action Plan for Environmental Protection for 2023-2025, approved by the Order of the Cabinet of Ministers of Ukraine No. 443-r dated April 21, 2021; "Water Strategy of Ukraine for the period up to 2050," approved by the order

of the Cabinet of Ministers of Ukraine dated December 9, 2022, No. 1134-r.

The development of productive sectors should be based on the rational use of river waters and natural resources, strengthening their protection and efficiency in order to ensure comfortable conditions for the population to live, work, and relax.

Proper consideration of river water forecasts makes it possible to regulate them both in natural conditions and in conditions affected by economic activity, implementing scientifically based measures to improve the conditions for their formation.

The current state of research on the issue, with an analysis of the main works. There are many methods for monitoring and assessing the condition of river waters, including comprehensive studies of water resources in the Volyn region. Scientific publications from various years indicate that anthropogenic pressure on the region's river waters increased sharply in the 1960s and 1970s and is associated with drainage reclamation and other works.

The issue of preserving Ukraine's river ecosystems is discussed in scientific publications by domestic and foreign researchers. In particular, studies by V. I. Osadchy, S. I. Prokopenko, and L. M. Shevchuk analyzed the hydrological regime of Ukrainian rivers, taking into account anthropogenic influences, climate change, and water use [14;15;23]. Research by M. M. Grebenyuk, N. A. Vovk, M. R. Zabokrytska, A. P. Pashkov, and others is devoted to studying water quality and pollution in river systems, in particular the accumulation of heavy metals, organic substances, and agrochemicals in water and bottom sediments [5; 6; 10;11;13; 18; 19; 20].

General characteristics of Ukraine's river water resources, directions and types of their comprehensive use and protection can be found in reference literature [12], as well as in the studies of A.V. Yatsyk [13; 14]. In connection with the growth of anthropogenic impact on water bodies in Ukraine, research into the problems of surface runoff formation has intensified. These issues are covered in the works of E.D. Gopchenko, V.I. Vyshnevsky, Y.O. Molchak, V.K. Khilchevsky, and V.V. Grebenya [1; 2; 13; 14; 15; 16; 17; 18; 19]. Hydroecological problems of rivers, hydrochemical characteristics of water composition, and the specifics of channel processes are presented in scientific publications and monographs by O. G. Obodovsky, S. G. Pankevich, A. V. Yatsyk,

V. K. Khilchevsky, and V. I. Osadchy [1; 2; 20; 21]. Basic concepts, terms, and data on water objects are provided in reference publications and textbooks. Scientists focus particularly on the protection and restoration of water resources in small and medium-sized watercourses, the number of which is constantly decreasing due to the canalization of riverbeds and the regulation of flow. Many publications by A. V. Yatsyk, V. K. Khilchevsky, M. O. Klymenko, I. P. Kovalchuk, and M. R. Zabokrytska justify water use measures aimed at improving the ecological condition of river basins and individual administrative districts [4; 12; 22; 23; 13]. Geoecological problems of medium river flows in Ukraine are widely represented in sectoral studies by I.Y. Myskovets, A.P. Pashkova, and Y.O. Molchak [7; 18; 20]. An analysis of the ecological quality of surface waters in the river basins of the Western region is presented in the works of L. G. Chyzhevska, Y. O. Molchak, M. R. Zabokrytska, I. M. Netrobchuk, N. M. Gulieva, and P. V. Pysarenko [24; 5; 7; 9; 10; 23]. The impact of drainage reclamation on floodplain and riverbed processes and the state of surface waters has been analyzed in the works of O.G. Obodovsky [2] and V.O. Fesyuk [10]. At the end of the XXth and beginning of the XXIst centuries, scientists focused their attention on studying river basin problems.

The basin approach to studying surface waters is currently a priority scientific direction. The main theoretical and methodological aspects of studying surface waters in medium- and large-scale river basins in Ukraine are outlined in the works of V. I. Vyshnevsky, A. V. Yatsyk, Y. O. Molchak, M. O. Klymenko, and I. P. Kovalchuk [15; 22; 24; 25; 7; 18; 14]. Many publications focus primarily on assessing anthropogenic impact and analyzing the effects of drainage reclamation. Foreign researchers such as M. Meybeck, B. Moss, and A. Allan [26; 27; 28; 30; 31] emphasize the importance of preserving river ecosystem services, the role of integrated water resources management (IWRM), and the participation of local communities in monitoring and preservation activities. However, adapting such approaches to Ukrainian realities requires further research and adaptation to the local socio-economic and natural context.

Identification of previously unresolved parts of the problem. Despite the existence of a solid theoretical basis, most studies focus on individual aspects of the problem and do not provide a comprehensive view of the state of Volyn's rivers as an interconnected natural environment. The lack of a unified integrated model for assessing environmental risk for river systems in the region indicates the need for further interdisciplinary research using modern

methods of spatial analysis, bioindication, and socio-ecological forecasting. Despite a significant number of studies devoted to the hydrological and ecological characteristics of river systems in Ukraine, the issue of water resources in the Volyn region remains insufficiently explored in scientific discourse. Most existing studies focus on general aspects of water use, the physical and chemical composition of water, or specific anthropogenic impacts, but there is no comprehensive interdisciplinary analysis that would simultaneously take into account the environmental, social, economic, and legal factors of river ecosystem degradation in Volyn. Issues related to the hydrological regime of small watercourses, the loss of the natural self-cleaning capacity of water bodies, and the degradation of coastal protection strips and wetlands, which are crucial for maintaining the region's water balance, remain insufficiently studied. In addition, the effectiveness of existing environmental protection programs and strategies for the conservation of Volyn's aquatic ecosystems, particularly at the local level, has not been properly evaluated. There is also a lack of empirical studies in contemporary scientific literature based on long-term monitoring of river systems in the region using geoinformation technologies, bioindication, and ecosystem service assessment. All these factors complicate the development of an effective strategy for managing Volyn's water resources based on the principles of sustainable development.

Defining the article's objective. The objective of the study is to conduct a comprehensive analysis of the ecological state of rivers in the Volyn region under current conditions, identify key threats to their functioning, and justify directions for conservation and sustainable use.

Materials and methods. The work utilised materials from the Kovel Hydrogeological and Land Reclamation Expedition, the Regional Water Resources Office in Volyn Oblast, the Volynvodproekt Institute, the Ecology Department of the Volyn Regional State Administration, the Volyn Statistics Department, the Hydrometeorological Institute, the Volyn Hydrogeological and Land Reclamation Party Laboratory, ecological passports of rivers, monographs, articles, and online publications. We also used desk analysis of archival data, literary sources, and research (field and laboratory). The research process involved a comprehensive approach combining elements of hydroecological analysis, cartography, bioindication, and critical review of scientific sources.

The following methods were used to conduct objective and thorough research:

- analysis of scientific and statistical sources, including reports from the Ukrainian Water

Resources Agency, regional water monitoring results, and scientific publications;

- comparative and analytical method - to compare data on the state of rivers in Volyn with other regions of Ukraine and Europe; Geoinformation analysis (GIS) for visualizing changes in river systems and identifying areas with an increased risk of degradation.

- expert assessment method - for analyzing the effectiveness of environmental protection measures and regional policy in the field of water resources protection;

- ecological interpretation method - for assessing water ecosystems based on indicators of pollution, regulation, landscape change, and biodiversity. These methods enabled an interdisciplinary approach to the study of Volyn rivers and provided a sound basis for substantiating the necessary measures for their protection.

Presentation of the main material. The territory of the Volyn region is characterized by a variety of natural conditions, which are mainly determined by the heterogeneity of the geological and geomorphological structure of the territory and the peculiarities of the climate, which in turn affect the distribution of surface waters, the nature of soils, and the flora and fauna. All these components of nature are closely connected

and create certain natural complexes that form river waters. The hydrological regime of Volyn's rivers is shaped by a temperate continental climate and characteristic seasonal unevenness of flow [18]. The majority of annual runoff occurs in the spring (March–April), when intense snowmelt causes high water levels and periodic floods, accounting for 60–70% of the annual runoff volume. During the summer months, rivers experience low water levels due to high evaporation and low precipitation. Autumn is marked by slight increases in water levels, while in winter the rivers are covered with ice and show consistently low water levels. Due to the flat terrain and low incline (less than 2 m/km), the rivers flow slowly, with wide floodplains and a tendency to become swampy. In the context of climate change (decreased snow cover, frequent summer droughts), there is a general trend toward a decrease in runoff and a shift in its peaks. Regulating runoff using reservoirs and canals, particularly within agricultural landscapes, further alters the natural hydrological cycle. The region's water resources include 137 rivers, 269 lakes, and 11 reservoirs, Table 1 (Fig. 1).

According to statistics from the Regional Water Resources Office in Volyn Oblast, as of October 1, 2025, there are 1,085 ponds in Volyn region. According to the existing administrative-

Table 1

Reservoirs of Volyn Oblast [28]

№	Name of water reservoirs, inhabited area, district	Rivers' names	Drainage basin area, km ²	Mirror area, hectares	Volume of reservoirs at NWR, million m³	
					full	useful
Water reservoirs in the Pripyat River basin						
1.	Bykhivske, Bykhiv village, Kamin-Kashyrsky district	bas. Pripyat River	35,7	78	1,54	1,46
2.	Hryvenske, Lyshnivka village, Kamin-Kashyrsky district	bas. r. Stokhid	30,9	48	1,45	1,25
3.	Kovelske, Kovel village	r. Turiya	1480,0	54	1,27	0,45
4.	Krymnovskoye, Krymno village, Kamen-Kashirsky district	bas. Pripyat River Channel Zalyudsky	21,7	56,4	1,20	0,62
5.	Krychevychi, Krychevychi village, Kovel district	bas. r.Pripyat Krichevit-sa o/s	22,3	51	2,04	1,29
6.	Staromosirsk, village of Staryi Mosir, Kovel district	bas. Pripyat River Stokhid River	34,6	78	1,51	1,51
7.	Tsyrske, village of Vyberta, Kamin-Kashyrsky district	bas. Pripyat River, Tsir River	22	62	1,68	1,67
8.	Shepelsk, village of Shepel, Lutsk district	bas. r. Serna	137,0	88,0	1,55	1,55
9.	Maryanivske Maryanivka village, Lutsk district	Lipa River	36,0	118,5	1,30	1,30
	Total for the basin:		1820,2	633,9	13,54	11,10
Water reservoirs in the Western Bug River						
1.	Korteliske, Kortelisy village, Kovel district	Lake Lyubovel	41,0	180,0	4,2	3,45
2.	Tursk, Tur village, Kovel district	Zabolotivsky Channel	163	1357,3	21,5	21,5
	Total for the basin:		204,0	1537,3	25,7	24,95
	Total for the region:		2024,2	2171,2	39,24	36,05

Table 2

Amount of rates by administrative Districts of Volyn region on October 1, 2025 [28]

Name of the administrative-territorial district	River basin	Quantity, units
Volodymyr-Volynskyi	Pripyat	43
	Western Bug	271
Kamin-Kashirsky	Pripyat	135
	Western Bug	-
Kovel	Pripyat	94
	Western Bug	47
Lutsk	Pripyat	488
	Western Bug	7
Total		1085
including	Pripyat	760
	Western Bug	325

territorial division, the largest number of ponds is recorded in Lutsk (495), Volodymyr-Volynskyi (314), Kamin-Kashirskyi (128), and Kovel (141) districts. The summary of the main parameters of ponds by administrative districts and river basins is presented in Table 2 [28].

The hydrographic network of the Volyn region belongs to the basins of the Pripyat and Western Bug rivers, but most of the rivers belong to the Pripyat. The main rivers often originate outside the region, with only a few (Turiya, Stokhid, Vyzhivka) flowing entirely through the territory of Volyn. The Pripyat River and its tributaries, the Styr, Turia, and Stokhid, are the largest rivers in the Dnieper basin in the region. The Western Bug flows along the western border with its tributary Luga and 24 rivers, which flow mainly from south to north with a slow current through the gentle terrain. Most rivers are shallow and not navigable. River network density is 0.25–0.47 km/km² for the Pripyat River

and 0.22–0.35 km/km² for the Western Bug River. Rivers are used for recreation, tourism, swimming, and fishing [18].

The rivers of the region have a flat regime with predominantly snow feed, although in recent years there has been a shift towards rain feed, which determines their level and runoff regimes. They are characterised by high spring floods and low low water levels, sometimes disrupted by summer and winter floods. The drainage regime is formed under the influence of physical and geographical factors - geology, relief and climate, which affect the distribution of drainage and the water content of rivers.

Hydrogeological conditions significantly influence the formation of low-water flow, which is related to the groundwater regime and erosion. The flow of rivers in the region is uneven throughout the year and varies depending on the water content of the year. Maximum flows

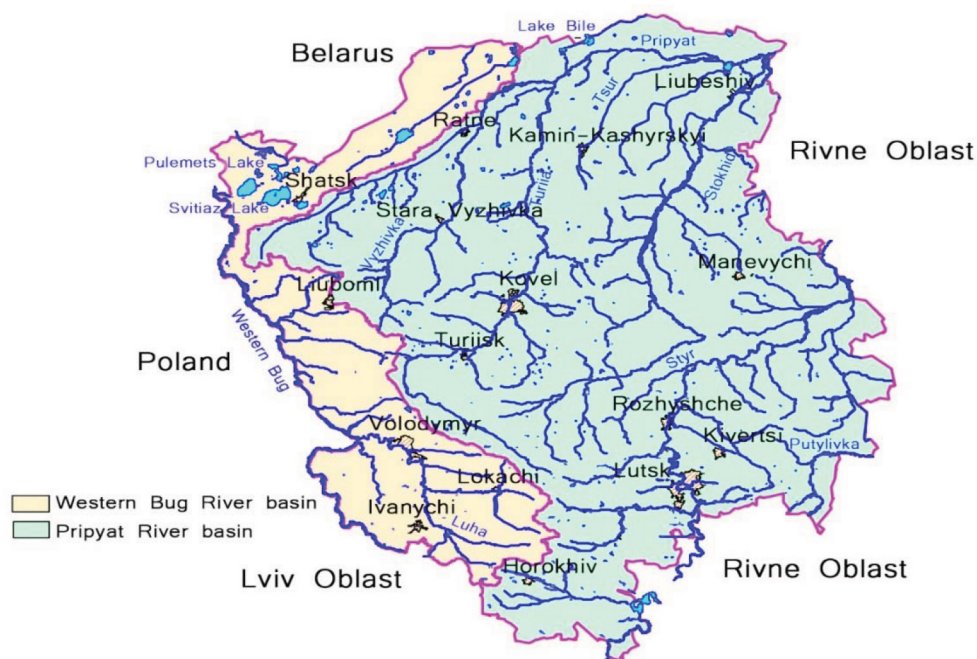


Fig. 1. Hydrological network of Volyn

are observed during spring floods and summer-autumn floods.

Most small watercourses are polluted by industrial, agricultural and municipal wastewater. Due to the reduction in the transport capacity of the river flow, they become silted up. The water regime of small watercourses is particularly sensitive to the reduction in groundwater levels during land reclamation and groundwater extraction [9].

The low technological culture of fertiliser use in agriculture worsens the water-physical properties of soils, affects the formation of runoff and sediments, and contributes to the eutrophication of watercourses. Many small river systems have dried up.

The solid runoff of Volyn rivers reflects the erosive activity of surface waters, especially in the upper reaches of the Pripyat tributaries on the elevations of the Volyn Upland. In the Volyn Polissya, the karst territory with sandy-clay deposits has weak water erosion and low runoff of mineral sediments. The solid runoff causes variable water turbidity, ranging from 3-5 g/m³ (Turiya) to 12-60 g/m³ (Styr), especially during torrential floods [18].

The thermal regime of the region's rivers depends on the air temperature, but this dependence is disrupted due to regulation (reservoirs, ponds) and the influence of groundwater with a different temperature. When the air temperature drops below zero, ice formations form on the rivers, and the ice period lasts 3–4 months. The ice cover is unstable, the rivers thaw and freeze several times, and complete clearing of ice occurs 5–10 days after thawing.

Focus on the study of the main rivers of the Volhyn region.

The Western Bug - is a river in Ukraine, Belarus and Poland, a right tributary of the Vistula. It is the only river in Ukraine that flows into the Baltic Sea. It originates in the northern edge of Podillia, flows through Volhynia from south to north and further serves as the state border with Poland. The river flows through Ukraine to the city of Ustyluh, and then along the border. The floodplain is narrow (up to 1 km), and the riverbed is winding. The river is 10 to 100 m wide and 0.5–4.5 m deep. There are 80 lakes in the Western Bug river basin in Volhynia, including the Shatsk Lakes (39 lakes), the largest of which is Lake Svitiyaz. A number of reservoirs have been built on the river. The river is navigable in its lower reaches [7]. The Western Bug is a natural border between Ukraine and Poland, which makes it very important for international water relations [29]. This fact is important for studying international water management and environmental standards between countries. The Western Bug is crucial to the ecosystem of the Vistula basin, influencing the

hydrological regime of Poland's rivers, particularly those flowing into the Baltic Sea. The river basin of the Western Bug is classified as class 5 in terms of water pollution, which indicates severe pollution [5;31]. The river basin covers an area of 3,102.08 km², which is 15.3% of the region's area. The main polluters are wastewater from the city of Volodymyr and surrounding settlements, as well as runoff from agricultural land. Thanks to its natural conditions, the Western Bug is a biosphere reserve for numerous species of plants and animals, including rare species of animals, in particular rare species of fish (ide, trout, grayling, dace, gudgeon, river minnow), as well as otters and beavers, which are important for maintaining the region's biodiversity [13].

The Luga is a right tributary of the Western Bug, whose source is located on the Gorokhiv Upland and flows into the Western Bug near the town of Ustyluh. The river is 93 km long, and its basin covers an area of 1,348 km². It is fed by groundwater and precipitation. It flows through the Lokachi, Ivanychi, and Volodymyr communities. It has several tributaries and over 20 ponds. Due to anthropogenic influence (land reclamation, dams, channel straightening), the hydrological regime has been altered, the flow has been reduced, and the sources have been silted up [18].

The Pripyat is the largest tributary of the Dnieper in terms of basin area, length, and water content, flowing through the Volyn, Rivne, and Kyiv regions of Ukraine and Belarus. It is considered one of the oldest rivers in Europe, formed after the last ice age [11]. After the Chernobyl accident in 1986, part of the river flowed into the exclusion zone, turning it into a natural laboratory for studying the restoration of ecosystems after radioactive contamination. Research has shown that the flora and fauna on the banks of the Pripyat are gradually recovering, despite radioactive contamination. The Pripyat River is one of the largest rivers without natural reservoirs, which helps to preserve its natural regime, although some artificial structures are used to regulate floods. The Pripyat River basin (upper reaches to the town of Ratne) and the Vyzhivka River are classified as Class 1 in terms of water pollution, which indicates their high quality. They cover an area of 3,153.28 km², which is 15.61% of the region's area. Pollution in these basins is minimal, and the water is characterized as "clean." The Pripyat River mainly flows through the Polissya lowlands among marshy banks. Its valley is weakly pronounced in the upper reaches and more distinct in the lower reaches, with a width of 5–8 km. The floodplain stretches along the entire course, with two terraces above the floodplain [18]. The upper reaches of the river are canalized, while further downstream it is

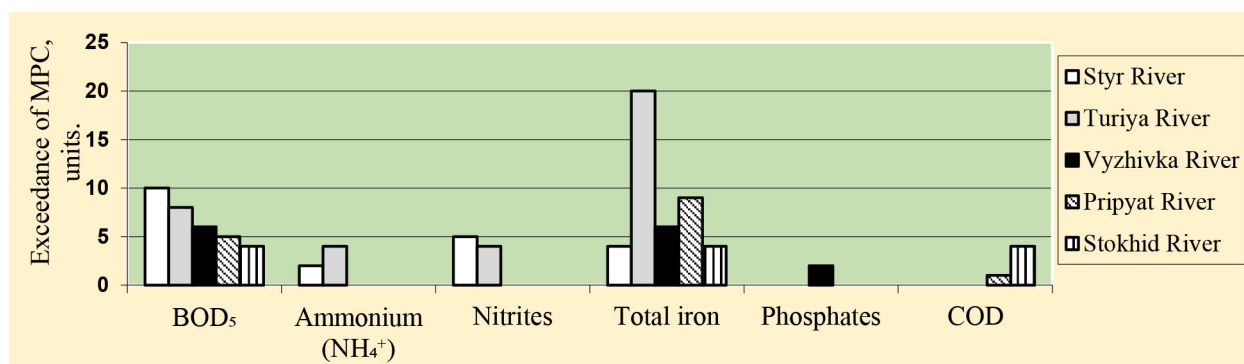


Fig. 2. Pollutants in the Pripjat River basin [11]

winding, with meanders, oxbow lakes, channels (in particular to Lake Nobel) and sandy islands. It has a mixed water supply, mainly from snowmelt. Its regime is characterized by prolonged flooding in the spring. The Pripjat freezes only in mid-December. The swamps in its basin affect the color of the water. Most of its tributaries are canalized; among the right-bank tributaries are the Turia, Stokhid, Styr, and Horyn. Monitoring since the 2000s has recorded pollution of the waters with organic and biogenic substances. The basin is experiencing eutrophication due to excess nitrogen and phosphorus, mainly from point sources. The most polluted rivers are the Horyn, Styr, and Turia, the latter due to effluents from enterprises in Kovel. In the Pripjat River, water quality varies: in general, the water is “clean” in terms of salt composition, but “moderately polluted” with toxic substances.

In 2019–2024, Pripjat remained contaminated: exceedances of MPCs for ammonium nitrogen, iron, chromium, and copper were stable, with peak values up to 10 MPCs (Fig. 2) [11]. At the same time, in terms of salt composition, the water remained “very clean,” and in terms of other indicators, “fairly clean” or “slightly polluted,” which corresponds to quality class II. According to I.M. Netrobchuk (2017–2023), the quality of water in Pripjat in the Volyn region is declining due to effluents from municipal enterprises, villages without centralized sewage systems, and farming [9]. In the Chernobyl exclusion zone, the river

has elevated toxic and radioactive contamination, which negatively affects its ecological condition (Fig. 3) [9].

The Stokhid is a right tributary of the Pripjat, 188 km long, with a basin of 3,125 km². It originates near the village of Semerynske (Volodymyr district). The upper reaches of the valley are distinct (up to 4.5 km wide), while further downstream the width ranges from 7 to 10 km. Below the village of Zayachivka, the river forms numerous branches. It is fed by precipitation, surface water, and groundwater. The Stokhid receives runoff from drainage systems and is connected to Lake Chervyshche by a canal. The riverbed is deepened and straightened for 50 km.

Near the village of Lyubeshiv, most chemical indicators of water are normal, but ammonium ions and COD exceed the norm, there are signs of organic pollution, without significant toxic or radioactive problems [18].

The Turiya is a right tributary of the Pripjat River, 184 km long. It originates in a swamp near the village of Zaturtsi and flows through the Polissya lowlands through several communities in Volhynia. The floodplain is bilateral, sometimes swampy, with oxbow lakes and lakes [18]. The river has a pronounced spring flood. The basin is forested, partially reclaimed (~20%), and there is a reservoir in Kovel.

The Turia flows through one of the largest wetlands in Western Ukraine. These wetlands within the Turia basin are critically important to

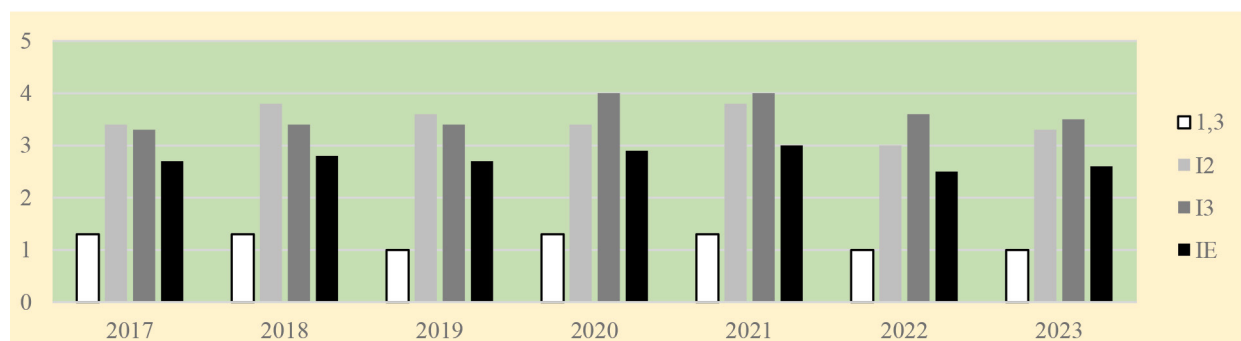


Fig. 3. Block and ecological indices of water quality in the Pripjat River (Richytsia village) (salinity index - I₁, saprobity index - I₂, toxic substances index - I₃, quality index - I_E)

the ecosystem as they help preserve biodiversity and stabilize the water regime. The Turia River was an important waterway in the Middle Ages, particularly for transporting goods between the Volhynian and Galician principalities. It was part of a larger system of waterways connecting the Dnieper and the Baltic Sea. There are natural mineral water springs in the vicinity of the Turia River that are used for therapeutic and health purposes, particularly in the regions near the cities of Kovel and Lutsk. The city of Kovel has the greatest impact on water pollution in the Turia River due to industrial wastewater, unauthorized connections to the sewage system, landfills, and violations of water protection regulations [18]. The water quality of the Turia River is generally good: pH, nitrite nitrogen, and chlorides correspond to class 1 (“excellent” condition), while the worst water quality indicators (dissolved oxygen, BOD₅, COD, and nitrates) belong to class 3 (“satisfactory”). The worst values were recorded in July (Table 3).

The Styr is a river 494 km long, 70 km of which are in Belarus, with the rest in Ukraine (Lviv, Volyn, and Rivne regions). It originates near the town of Brody, and its basin covers 11,200 km². The valley is trapezoidal in shape and runs through the Podillia Upland and the Polissia Plain. In the upper reaches, the relief is rugged with ravines, in the middle part it is hilly, and in the lower part it is flat and marshy. The bottom is sandy, with stones, silt, and pits. Spring floods last 2–5 weeks, flooding the valley. The water is clear, and there are three reservoirs in the basin. The Styr is one of the most important rivers in Volhynia, and its flow is highly variable. It is known that in the spring, the water in the Styr River can rise to 4–5 m, causing regular

floods. This makes the Styr an important object for studying hydrological changes in the context of climate change. The Styr is an example of a river with a dominant underground water supply in certain parts of its basin. This reduces the rate of water level fluctuations and allows the river to remain relatively stable even during droughts. The Styr River is undergoing negative changes in its ecosystems due to the impact of land reclamation. However, natural processes have been restored in some sections of the river, in particular through the creation of ecological corridors. The Styr River basin (outside the city of Lutsk) is classified as class 5 in terms of water pollution, which indicates severe pollution. It covers an area of 3,102.08 km², which is 15.3% of the region’s area. The main sources of pollution are wastewater from the city of Lutsk and surrounding settlements, as well as agricultural runoff. The water quality of the Styr River remained stable, mostly corresponding to category 2 of class II quality (“very good,” “clean”), with the exception of 2009, 2010, and 2017, when category 3 (“good,” “fairly clean”) was recorded. The water quality is affected by wastewater from housing and communal services and enterprises in Mlyniv, Dubno, and Lviv region (through tributaries). The influence of the city of Lutsk is reflected in elevated calcium concentrations, Cr⁶⁺ and dichromate oxidizability. The Styr has stable water quality, although anthropogenic impact and pollution from wastewater sometimes reduce its ecological status [18; 11].

The Tsyr is a right tributary of the Pripyat River, flowing from a marshy area near the village of Yalovatsk in the Kamin-Kashirsky District. Its catchment area is 538 km², and the river is 52 km long. The bed of the Tsyr is straightened and serves as the main channel of the drainage

Table 3

Water quality of the Turia River within the city of Kovel according to the “Methodology for classifying surface water bodies...”[18]

Indicators	MPV quality class			
	29.05.2024 Sample №1	15.06.2024 Sample №2	11.07.2024 Sample №3	16.08.2024 Sample №4
Hydrogen index pH, units pH	7,3 excellent	7,7 excellent	7,5 excellent	7,3 excellent
Dissolved oxygen, g O ₂ /dm ³	11,4 excellent	9,3 excellent	3,2 satisfactory	8,1 excellent
Biological oxygen consumption (BOD ₅), mgO ₂ /dm ³	2,6 excellent	2,4 excellent	5 satisfactory	2,5 excellent
Chemical oxygen demand, mgO/dm ³	21,6 good	40,3 satisfactory	30 satisfactory	17,6 good
Ammonium nitrogen, mgN/dm ³	0,36 good	0,18 good	0,19 good	0,21 good
Nitrate nitrogen, mgN/dm ³	0,56 excellent	2,74 satisfactory	2,81 satisfactory	2,97 satisfactory
Nitrite nitrogen, mgN/dm ³	0,003 excellent	>0,003 excellent	0,003 excellent	0,003 excellent

system. The catchment area occupies the Verkhniopripiatskaya accumulative lowland. The valley is indistinct, 1 to 3 km wide with barely noticeable slopes, the floodplain is swampy and peaty, and the riverbed is marked by meanders and branches. In addition, there are six karst lakes in the catchment area [7].

The Vyzhivka is a right tributary of the Pripyat River, 81 km long, with a basin area of 1,272 km². It flows through the Polissya Lowland in the Kovel District and empties into the Pripyat River near the town of Ratne. The valley is not very pronounced, and the floodplain is swampy. The river is used for land reclamation and drainage, and two ponds have been constructed. Monitoring reveals excessive BOD₅ and iron concentrations, indicating organic pollution. The ecological condition of the river, especially in its middle and lower reaches, is unsatisfactory and requires restoration [7].

The Vyzhivka is a right tributary of the Pripyat River, 81 km long, with a basin area of 1,272 km². It flows through the Polissya Lowland in the Kovel District and empties into the Pripyat River near the town of Ratne. The valley is not very pronounced, and the floodplain is swampy. The river is used for land reclamation and drainage, and two ponds have been constructed. Monitoring reveals excessive BOD₅ and iron concentrations, indicating organic pollution. The ecological condition of the river, especially in its middle and lower reaches, is unsatisfactory and requires restoration [20].

After calculating the Redfield number, it has been found that nitrogen was the limiting element for the Luga, the Vyzhivka, and the Stokhid rivers. This indicates that blue-green microalgae predominate in the waters of these rivers. In other rivers, namely the Turia and Styr, the limiting element is phosphorus, which contributes to the spread of green algae [11].

In general, it has been determined that these rivers had an average degree of purification,

which is not critical for the development of eutrophication. Only in recent years of observation in the Vyzhivka River has it been found that the purification capacity has become below average (Fig. 4).

Thus, there is a noticeable tendency towards phosphorus limitation, primarily for the Turia River, accompanied by the predominance of green algae communities. The balance of elements (N and P) according to Redfield's number is observed mainly for the Styr River, which indicates the absence of active eutrophication processes in the presented series of years [20].

Thus, Redfield's calculation revealed that for the Vyzhivka, the Luga, and the Stokhid rivers, in the vast majority of years, nitrogen was the limiting factor, leading to the development of algae (blue-green) communities. For the Turia and the Styr rivers, the limiting factor is mostly phosphorus, which causes the development of green algae (protocock) communities. The rivers Styr, Stokhid, Turia, Western Bug, and Luga are characterized by a decrease in maximum flows during 1991-2020. The Vyzhivka River at both hydrological stations is characterized by an increase in maximum flow. The Pripyat River (Rychytsia hydrological station) and downstream (Lyubyaz hydrological station) has maximum flows in different directions [25].

The main environmental problems of river systems in the Volyn region are:

- the disruption of the natural hydrological regime due to large-scale drainage reclamation, which led to a decrease in groundwater levels. A reduction in the area of wetlands and floodplains, and a decrease in the base (underground) flow of rivers, which caused small rivers to dry up during the summer and autumn low water period, a sharp increase in flooding in the spring, and a decrease in the stability of river ecosystems to climatic fluctuations;

- an anthropogenic transformation of riverbeds and floodplains, i.e., straightening, deepening of riverbeds, and their canalization, which led to the

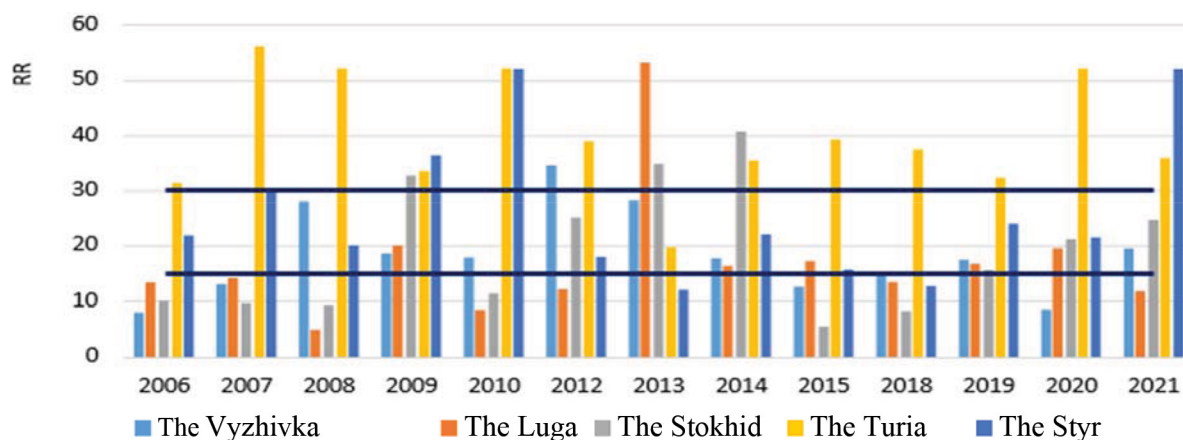


Fig. 4. Long-term average dynamics of the Redfield number in the water of rivers in the Volyn region

loss of river sinuosity, reduction of floodplain areas, disruption of the hydrological connection between the riverbed and adjacent territories, which in turn caused the degradation of channel-floodplain ecosystems, a reduction in biodiversity, and a deterioration in water self-purification processes;

- the deterioration of surface water quality due to diffuse runoff from agricultural land, domestic wastewater from settlements, drainage water from drained peatlands, which led to an increase in the content of biogenic substances, eutrophication of water bodies, and unstable oxygen conditions during the low-water period;

- the degradation of small rivers has led to limited water availability and high sensitivity to local influences, resulting in the partial or complete disappearance of individual watercourses from the region's hydrographic network.;

- the intensification of climate change, in particular, longer periods of drought, uneven precipitation, rising air temperatures, which exacerbates water shortages, ecological instability of river systems, and the risk of degradation of aquatic ecosystems.

The main ways to preserve and restore the region's river systems should be:

- the restoration of the natural hydrological regime through optimization of drainage systems, regulation of drainage channels, re-wetting of degraded peatlands, restoration of the role of wetlands as natural water reservoirs;

- the renaturalization of river channels and floodplains by restoring the sinuosity of straightened sections, expanding and preserving floodplains, and eliminating excessive engineering regulation of channels;

- the reduction of diffuse pollution through the preservation and restoration of coastal protection strips, the introduction of soil protection technologies in agriculture, and the reduction of biogenic substances entering watercourses;

- the improving wastewater treatment by modernizing treatment facilities, controlling unauthorized discharges, and conducting environmental monitoring of small settlements;

- a basin-based approach to water resource management through integrated management at the level of the Pripjat and Western Bug basins, combining environmental and water management interests, and community participation in river conservation;

- the adaptation to climate change through the development of nature-based solutions, restoration of forests, wetlands, and floodplains, and improvement of the ecological sustainability of aquatic ecosystems.

Thus, the river systems of the Volyn region are in a tense ecological state, caused by a combination of anthropogenic influences and modern climate

change. The preservation and restoration of rivers is only possible with a comprehensive, basin-wide, and ecosystem-based approach that combines environmental, hydrological, and socio-economic measures.

Conclusions

Based on the research, it has been found that:

1. The rivers of Volyn play a key role in maintaining the ecological balance of the region, providing water resources, biodiversity, and natural equilibrium.

2. The main challenges for the region's river ecosystems are related to water pollution, artificial regulation of river beds, degradation of coastal areas, and disruption of the natural hydrological regime.

3. The existing water resource management system is fragmented, with low-level environmental protection measures and insufficient coordination between authorities.

4. Environmental monitoring of rivers should be expanded to include bioindication and geoinformation methods.

5. Integrated water resource management, an ecosystem approach to riverbed restoration, and the development of legal and financial mechanisms for the protection of river systems are recommended.

6. The protection of Volyn's rivers should become a priority for regional environmental policy, with the active participation of local communities and the scientific community.

The implementation of comprehensive environmental protection measures is key to preserving these water systems as sources of life for present and future generations.

Scientifically based recommendations.

Based on the analysis, a number of practical and strategic recommendations have been formulated, the implementation of which will contribute to the conservation and restoration of river ecosystems in Volyn and ensure their sustainable functioning:

1. **Integrated water resources management (IWRM).** It is necessary to combine environmental, economic, and social approaches to water resource use, taking into account the specific characteristics of each basin. This requires the development of water resource management plans at the river basin level in accordance with European requirements, in particular the provisions of the EU Water Framework Directive.

2. **Expansion of the water monitoring system.** It is advisable to introduce systematic comprehensive monitoring, including physical, chemical, biological, and hydrological parameters, with a particular focus on small watercourses that are most sensitive to external influences.

3. Renaturalization of riverbeds and restoration of riparian ecosystems. It is recommended to carry out river clearing measures only in cases of critical necessity, instead restoring the natural sinuosity of riverbeds, wetlands, coastal areas, and meadows as elements of self-regulation of the water system.

4. Limiting anthropogenic pressure and introducing environmentally safe practices. It is necessary to strengthen control over the discharge of untreated wastewater, restrict development in coastal areas, regulate agrochemical pressure near rivers, and encourage the use of nature-based measures.

5. Development of environmental education and public awareness. Effective protection of rivers is impossible without changing public attitudes towards them. It is advisable to implement educational programs

and environmental awareness campaigns, and to involve young people and local communities in monitoring and nature conservation initiatives.

6. Development of legal and financial mechanisms to support environmental protection measures. It is necessary to improve the regulatory framework for water protection and ensure targeted funding for river ecosystem restoration projects from state, local, and international sources.

7. Deepening scientific research. It is advisable to initiate research programs for long-term study of Volyn's river systems using geoinformation technologies, bioindication methods, and mathematical modeling of ecosystem processes. The results obtained can serve as a basis for the formation of regional strategies, water resource management programs, and the implementation of environmental protection projects.

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Річкові системи Волинської області: стан, проблеми та шляхи збереження

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АНОТАЦІЯ

Дане дослідження спрямоване на всебічне вивчення екологічного стану річок Волинської області у сучасних умовах, визначення ключових загроз для водних екосистем та обґрунтування шляхів їх збереження і сталого використання. Виконуючи дану роботу було застосовано методи дослідження: порівняльно-географічного аналізу, математичної статистики, картографічний, польових спостережень й узагальнення, з використанням комплексних підходів (генетичного, історичного, системного, басейнового). Новизна дослідження полягає у розвитку підходів до аналізу та оцінки антропогенних змін у водозбірних територіях незначних водотоків з метою вирішення завдань з поліпшення природоохоронної ситуації в межах Поліського краю та Лісостепової зони Волинської області. У роботі подано систематизований виклад сучасного стану водозбірних територій річкових систем Волині, проведено аналіз і оцінку різновидів антропогенного впливу на маловодні водотоки регіону. Розкрита якісна та кількісна характеристики різних навантажень на басейни річок та розроблені відповідні індекси їх оцінки щодо трансформації їх природного середовища. У роботі коротко описано природно- кліматичні та фізико-географічні передумови формування річкового стоку. Оцінено екологічний стан річкових систем Волині та вплив різних галузей господарства на нього, визначено ключові чинники деградації та запропоновано заходи для зменшення забруднення і поліпшення водного середовища. Розглянуто нормативні показники якості води та шляхи охорони і подальше раціональне використання річок у народному господарстві. На основі аналізу сформульовано низку практичних та стратегічних рекомендацій, реалізація яких сприятиме збереженню і відновленню річкових екосистем Волині та забезпеченню їхнього сталого функціонування, зокрема інтегроване управління водними ресурсами (IWRM), розширення системи моніторингу води, ренатуралізація русел і відновлення прибережних екосистем, обмеження антропогенного навантаження та впровадження екологічно безпечних практик, розвиток екологічної освіти та просвіти населення.

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антропогенне навантаження; річковий стік; річковий басейн; екологічний стан; природне середовище; забруднення; стає водокористування; водні ресурси; гідроекологія; моніторинг довкілля.