UDC 556.51:502.51(477)

Alla Naumivna Nekos,
DSc (Geography), Prof., Head of the Department of Ecological Safety and Ecological Education
Karazin Institute of environmental sciences, V. N. Karazin Kharkiv National University
4 Svobody Sq., Kharkiv, 61022, Ukraine,
e-mail: alnekos999@gmail.com, http://orcid.org/0000-0003-1852-0234;
Mariia Volodymyrivna Boiaryn,
PhD (Geography), Associate Professor, Department of Ecology and Environmental Protection,
Lesya Ukrainka Volyn National University, 13 Voli Ave., Lutsk, 43025, Ukraine,
e-mail: mariasun140314@gmail.com, http://orcid.org/0000-0001-9822-5897;
Maria Lugowska,
Dr. Eng., Assistant Professor at the Institute of Agriculture and Horticulture,
University of Natural Sciences and Humanities, Prusa str., 14, 08-110 Siedlce, Poland,
e-mail: maria.lugowska@uph.edu.pl, http://orcid.org/0000-0001-5284-7965;
Oksana Oleksandrivna Tsos,
Lecturer, Department of Ecology and Environmental Protection,
Lesya Ukrainka Volyn National University,
e-mail: oksana.tsos1972@gmail.com, http://orcid.org/0000-0002-9679-9413;
Iryna Markivna Netrobchuk,
PhD (Geography), Associate Professor, Department of Geography,
Lesya Ukrainka Volyn National University,
mail: iryna.nim@gmail.com https://orcid.org/0000-0002-8633-7426

ASSESSMENT OF THE ECOLOGICAL CONDITION OF THE WESTERN BUG RIVER BASIN ACCORDING TO THE MACROPHYTE INDEX FOR RIVERS (MIR)

А. Н. Некос, М. В. Боярин, М. Луговська, О. О. Цьось, І. М. Нетробчук. ОЦІНКА ЕКОЛОГІЧНОГО СТАНУ РІЧОК БАСЕЙНУ ЗАХІДНОГО БУГУ ЗА ІНДЕКСОМ МАКРОФІТІВ (MIR). *Для відновлення та збереження оптимального екологічного стану басейну Західного Бугу необхідним є дотримання стратегічних принципів раціонального природокористування у межах водозборів малих річок. На території Волинської області найбільшому антропогенному впливу піддаються річки-притоки Луга та Студянка. Дано екологічну оцінку якості води за станом макрофітів, оскільки макрофіти дозволяють визначити ступінь деградації поверхневих вод, перш за все, з погляду їх трофності. Для визначення екологічного стану річок басейну Західного Бугу та для проведення досліджень було закладено три тестові ділянки довжиною не менше 100 м. кожна, на двох притоках першого порядку - річках Луга та Студянка. Для визначення MIR (Макрофітового індексу річок) на тестових ділянках русла було відібрано 42 індикаторних видів макрофітів серед яких по 1 виду належить до відділу Polipodiophyta та Equisetophyta, 40 видів до відділу Magnoliophyta з них 15 належать до класу Magnoliopsida, та 25 належать до класу Liliopsida. Під час проведення досліджень у межах тестової ділянки русла річки № 1, було виявлено 23 види макрофітів, серед них переважають прибережні рослини та рослини з плаваючим листям; на тестовій ділянці № 2 виявлено 35 видів макрофітів, що відносно рівномірно представляють усі екологічні групи рослин. На тестовій ділянці № 3, під час дослідження екологічного стану води річки Студянка, було виявлено 19 видів макрофітів, серед яких переважають прибережні рослини. Згідно класифікації показника MIR, ці річки належить до водотоків низинних, за типом макрофітів – M-VIII (річки органічні). В результаті розрахованого (MIR) встановлено, що якість води у річці Луга на тестовій ділянці 1 (с. Завидів) має добрий екологічний стан MIR становить 39,0; а на тестовій ділянці 2 (смт. Володимир Волинський) має задовільний або помірний екологічний стан MIR становить 31,56; у річці Студянка, на тестовій ділянці 3 (смт. Устилуг) має задовільний або помірний екологічний стан MIR становить 28,31.*

Ключові слова*: річка, біоіндикація, макрофіти, екологічний стан річок, індекс макрофітів, класи якості води, екологічна оцінка якості води.*

А. Н. Некос, М. В. Боярин, М. Луговская, О. А. Цёсь, И. М. Нетробчук. ОЦЕНКА ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ РЕК БАССЕЙНА ЗАПАДНОГО БУГА ПО ИНДЕКСУ МАКРОФИТОВ (MIR). *Для восстановления и сохранения оптимального экологического состояния бассейна Западного Буга необходимо придерживаться стратегических принципов рационального природопользования в пределах бассейнов малых рек. На территории Волынской области самое большое антропогенное влияние оказывается на реки Луга и Студянка. Представлено экологическую оценку качества воды за состоянием макрофитов, поскольку макрофиты позволяют определить степень деградации поверхностных вод, прежде всего, с точки зрения их трофического состояния. Для определения экологического состояния рек бассейна Западного Буга и для проведения исследований было заложено 3 тестовых участка длиной не менее 100 м каждый, на двух притоках первого порядка – реках Луга и Студянка. Для определения MIR не тестовых участках русла было отобрано 42 индикаторных вида макрофитов, среди которых по 1 принадлежит отделу Polipodiophyta и Equisetophyta, 40 видов принадлежит отделу Magnoliophyta из них 15 принадлежит к классу Magnoliopsida, и 25 принадлежит к классу Liliopsida. Во время проведения исследований на тестовом участке русла речки № 1, было выявлено 23 вида макрофитов, среди которых преобладают прибрежные растения и растения с плавающими листьями; на тестовом участке №2 выявлено 35 видов макрофитов, которые относительно равномерно представляют все экологические группы растений. На тестовом участке №3, во время исследования экологического состояния воды речки Студянка, определено 19 видов макрофитов, среди которых преобладают прибрежные растения. Согласно классификации показателя MIR эти реки принадлежат к водотокам низменным, за типом макрофитов M-VIII (реки органические). В результате вычисленного индекса (MIR) установлено, что качество воды в*

https://doi.org/10.26565/2410-7360-2021-54-24

реке Луга на тестовом участке 1 (д. Завидов) имеет хорошее экологическое состояние и составляет 39,0; на тестовом участке 2 (пгт. Владимир-Волынский) имеет удовлетворительное экологическое состояние MIR составляет 31,56; в реке Студянка на тестовом участке 3 (пгт. Устилуг) имеет удовлетворительное состояние, а индекс MIR составляет 28,31.

***Ключевые слова**: река, биоиндикация, макрофиты, экологическое состояние рек, индекс макрофитов, класс качества воды, экологическая оценка качества воды.*

Introduction. The river basin, as well as small rivers located within its catchment area, is an integrated ecological, hydrological, and economic unit with clear boundaries and a set of natural conditions. Increasing the resilience of the river basin geosystem is impossible without constant monitoring of the dynamics of natural resources and the factors of negative impact. A significant part of the water management complex of the Volyn region is the Western Bug river basin, which has a significant degree of development. Also, the state border between Ukraine and Poland runs along the watercourse, the river is a cross-border, and the tributary basins are located on the territory of both states. Therefore, to restore and preserve the optimal ecological condition of the Western Bug river basin, it is necessary to adhere to the strategic principles of rational nature management, within the small rivers catchment areas.

Today, most rivers in Ukraine in general and in the Volyn region, in particular, are polluted by ordinary human negligence. They play a very important role in the life of communities, satisfying household, industrial and technical needs, recreation, etc. Therefore, the basin of any river due to its economic use is subject to certain anthropogenic pressures. Due to this, small rivers are the most vulnerable to anthropogenic impact. The basins of small rivers have undergone significant plowing of catchments, the excessive density of their row crops, reclamation, low forest cover, which intensified the erosion processes, increased their siltation and overgrowing, changed the water and physical properties of soils, thermal and water balance disturbed groundwater, as well as the conditions of runoff formation [10, 12]. The situation is further more complicated by the fact that over the past 25 years there has been a tendency to actively build up the banks and floodplains of rivers, as well as contrary to the law, agricultural use of water lands. In this regard, the rivers Luha and Studyanka, the right tributary of the Western Bug, flowing through the three southern districts and the city of Volodymyr-Volynskyi lead to deterioration of the ecological condition of both the waterway of the Western Bug and these tributaries, which is rapid overgrowth. riverbeds, shallowing, and waterlogging. The main sources of anthropogenic impact on rivers are sewage treatment plants built in the 70's last century in need of reconstruction, landfills on floodplain terraces, filtration fields, etc. We should also underline that in the last twenty years no reclamation work has been carried out to clear the silted sources of rivers, which leads to their shallowing [9, 11, 14]. The problem is exacerbated by the fact that in recent years there has been strong low water - rivers are filled only 70% of normal. Thus, there is no doubt that the assessment of the ecological condition of small rivers, which include Luha and Studyanka, is important because the water quality of the Western Bug river itself depends on them, so the topic is important and relevant.

Several scientific studies are devoted to the assessment of river water quality in the Western Bug river basin from various aspects. Ecological assessment of water quality of rivers of Volyn region and their cartographic analysis were performed by V. D. Romanenko, A. V. Yatsyk, I. V. Hopchak [7, 15, 16]. Analysis of the geoecological situation and the results of the ecological assessment of the current state of the Luha river basin is presented in the scientific works of I. M. Netrobchuk, O. R. Perkhach, F. M. Kiptach, A. V. Yatsyk, I. V. Hopchak, T. O. Basyuk, M. I. Syrotyuk [9, 11, 14, 16, 18]. The impact of the water management complex of Volodymyr-Volynskyi on the ecological condition of the Luha River was analyzed by V. O Fesyuk [14].

The analysis of scientific publications on ecological assessment of river water quality, which were performed by different authors, testifies to their carrying out mainly on hydrochemical indicators. In this regard, there is a need for environmental assessment of water quality in some river basins of Western Polissya, in particular the rivers of the Western Bug river basin, conducted in the framework of research work of the Department of Ecology and Environmental Protection of the Lesya Ukrainka Eastern European National University, by the state of macrophytes. Because macrophytes allow determining the degree of degradation of surface waters, primarily in terms of their trophic. The nutrients content in river waters varies in space and time, which is influenced by many factors: the river's ability to self-clean, meteorological indicators and seasons, anthropogenic impact. Chemical and physical methods (mainly instrumental) of surface water quality assessment allow determining pollution during sampling at the same time. While biological research methods allow determining the impact of pollutants in the long run.

Macrophytes are a mandatory component of the ecosystems of most reservoirs and watercourses, they influence hydrochemical and hydrobiological processes, playing an important and multifaceted role in the life of the reservoir. First of all, they are an important component of the power supply chain of the hydroecosystem and perform the function of a mechanical filter, clarifying the water, protecting the shores of reservoirs from erosion [1, 3, 8, 25, 30]. Also, macrophytes in their tissues can accumulate significant concentrations of various contaminants - heavy metal ions, radionuclides, pesticides, etc. However, in addition to the positive, aquatic vegetation can play a negative role in the reservoir: secondary pollution of the reservoir due to the death of phytomass, or the accumulation of organic matter due to the ingress of nutrients into watercourses.

Aquatic organisms are exposed to the aquatic environment, are sensitive to the content of pollutants in water [8, 25, 26, 29]. The method of determining the macrophytes index (MIR) is based on studies conducted in European countries. In the United Kingdom, the Mean Trophic Rank (MTR) system is widespread, in which 128 species of macrophytes are represented, among which the higher plants are decisive, and mosses and algae are represented in smaller numbers. Each species is assigned the rank of the value of the indicator. This technique is also used in other countries (Poland, Spain, the Czech Republic, Russia, Kazakhstan, etc.). The technique (MTR) has been used in research for many years. Since 2008, the River Nutrient Macrophyte Index system has also been used to monitor macrophytes in the United Kingdom [2, 5, 6, 17, 27, 28, 29, 30].

In Germany, a methodology has been developed and tested that allows us to assess the degree of overall river degradation and is not limited to the aspect of eutrophication. The System Reference Index (RI) (Schaumburg I in 2004) was developed in 2004. This method is widely used in the river monitoring system in Germany to assess the ecological status of surface waters following the Water Framework Directive. Studies in France are conducted according to the IBMR methodology (Haury I in 2006), which combines two calculated bioindication indicators. One indicator shows the level of the trophic environment, the another one determines the degree of ecological tolerance of the species (steno- and eurybiont). To assess the ecological condition of the rivers of the Scandinavian countries, an original method developed by Danish scientists (Baattrup-Pedersen I in 2001) is used. It is based on Shannon-Weaver biodiversity indices. The Polish method of assessing the ecological status of rivers (Makrofitowa Metoda Oceny Rzek (MMOR)) is based on the English method Mean Trophic Rank (MTR) and the French method Indice Biologique Macrophytique Riviere (IBMR), which have long been used for research[23, 24, 25]. It was first described in 2006, and in 2010 it was published in the form of a textbook . The method is based on the determination of quantitative and qualitative indicators of assessment of aquatic and coastal macrophytes presented on the studied segment of the water body. Based on the results of the study of the species composition of macrophytes, determine the indicator Makrofitowy Indeks Rzeczny (MIR), which allows for assessing the ecological status following the EU Water Framework Directive [25, 29, 31].

In Belarus, the assessment of the ecological status of rivers is based on the determination of the biological index of macrophytes according to the IBMR method [13]. A variant of the classification scheme of small rivers was created taking into account the phytocoenotic diversity of vegetation and assessment of their ecological condition.

In Ukraine, research in this area is conducted at the Ukrainian Research Institute of Environmental Problems and is based on the method (MMOR) (Vasenko O., Korobkova G.), which substantiates the possibility of using groups of aquatic macrophytes to assess the ecological status of forest-steppe and steppe rivers [4]. Similar studies concerning the assessment of the ecological status of the ecosystems of the Pripyat basin by higher plants were conducted by M. O. Klimenko and Yu. R. Grokhovska [3]. We conducted a study of groups of aquatic macrophytes to assess the ecological status of the rivers of Volyn Polissya which are tributaries of the Pripyat - Turia, Vyzhivka, Tsyru [1, 20, 21, 22, 23, 32].

The purpose of article. The purpose of article aims to assess the ecological status of the rivers of the Western Bug river basin using bioindication methods and determination of the Macrophyte Index for Rivers (MIR).

Materials and Methods. Research methods are expeditionary, methods of mathematical statistics end bioindication methods and determination of the Macrophyte Index for Rivers (MIR).

To determine the ecological status of the rivers of the Western Bug and to conduct research, three test sites with a length of at least 100 m were laid each on two tributaries of the first order, the rivers Luha and Studyanka. The first test section of the Luha riverbed is located in the village of Zavydiv village (upper course), the second test section of the Luha riverbed - in the city of Volodymyr-Volynskyi (500 m below the discharge of municipal treatment facilities), the third test section of the Studyanka riverbed - in the Ustyluh town (lower reaches of the river).

To determine the MIR (*Macrophyte Index for Rivers*), 42 indicator species of macrophytes were selected, of which 1 species belongs to the division Polipodiophyta and Equisetophyta, 40 species to the division Magnoliophyta, of which 15 belong to the class Magnoliopsida, and 25 belong to the class Liliopsida.

Performed in the river basin field studies allow to the calculation of the *Macrophyte Index for Rivers* (MIR), performed by the formula [25, 29]:

$$MIR = \sum (L_i \cdot W_i \cdot P_i) / \sum (L_i \cdot P_i) \cdot 10,$$

where

MIR - Macrophyte Index for Rivers;

L_i - the quantitative value of the indicator for the specified species;

W_i - the weighting factor for the species;

P_i – the coverage ratio of the specified type on a 9-point scale.

The MIR can be calculated from 10 (most degraded rivers) to 100 (least degraded rivers). In the case of lowland rivers, the highest MIR cannot exceed 60. 151 indicator species of macrophytes are used in the calculation. The methodology limits the MIR index for 5 ecological status classes for each macrophytic river type developed according to the EU Water Framework Directive, where each water ecological status class corresponds to a status: very good, good, moderate or satisfactory, bad and very bad [25, 29,31]. The classification of the studied sections of the river is done by comparing the calculated MIR index to the classification indicators that correspond to the type of river (lowland, upland, or mountain) and are shown in Table 1.

Table 1

Classification of the MIR indicator to determine the ecological state of rivers [25]

Type of macrophytes		**Type of water-**	**Ecological state**				
			Very good	**Good**	**Moderate**	**Bad**	**Very bad**
M-1	Alpine watercourses	Upland and mountain watercourses	≥65,6	(65,6 – 50,7>	(50,7 – 38,8>	(38,8– 24,0>	<24,0
M-II	Silicon rivers		≥61,8	(61,8 – 48,1>	(48,1 – 37,0>	(37,0 – 23,3>	<23,3
M-III	Carbonate rivers		≥55,4	(55,4 – 42,0>	(42,0 – 31,4>	(31,4 – 18,0>	<18,0
M - IV	High-rise watercourses of lowland character		≥48,3	(48,3 – 37,7>	(37,7 – 27,0>	(27,0 – 16,4>	<16,4
M - V	Large upland rivers		≥46,5	(46,5 – 37,8>	(37,8 – 29,0>	(29,0 – 20,3>	<20,3
M - VI	Sandy rivers	Lowland watercourses	≥46,8	(46,8 – 36,6>	(36,6 – 26,4>	(26,4 – 16,1>	<16,1
M- VII	Stony and gravel rivers		≥47,1	(47,1 – 36,8>	(36,8 – 26,5>	(26,5 – 16,2>	<16,2
M- VIII	Organic rivers		≥44,5	(44,5 – 35,0>	(35,0– 25,4>	(25,4 – 15,8>	<15,8
M - IX	Large lowland rivers		≥44,7	(44,7 – 36,5>	(36,5– 28,2>	(28,2 – 20,0>	<20,0

To carry out a comparative analysis of the ecological status of water quality of the rivers Luha and Studyanka by hydrochemical indicators and determined according to MIR " *Macrophyte Index for Rivers*" [25] was used the results of laboratory studies performed according to guidelines in the instrumental and laboratory control of the State Ecological Inspectorate in Volyn region [19].

Research results

According to the physical and geographical zoning, the basins of the rivers Luha and Studyanka, a tributary of the first order of the river Western Bug, are located in the southwest of the Eastern European plain in Podilska physical and geographical country, physical geographical region - Volyn Upland areas (western part), Novovolynsk and Lokachinsky physical-geographical districts. Landscape units loodplains and runoff valleys are typical - Meadow floodplains of small rivers of the Volyn Upland with grassy - grass - sedge meadows on the meadow - swamp soils and peatlands, significantly drained; landscape units of non-terraced slopes - undivided first and second forest terraces with shallow chernozems with low humus and podzolic under arable lands on the site of oak and hornbeam forests; landscape units interfluve - gently convex peaks of forest belts, covered in the past with oak groves with an admixture of other deciduous species, on chernozems podzolic and shallow low humus, plowed [18, 33].

The Luha River is a right tributary of the first order of the Western Bug river. The catchment area is – 1351,39 km2, length – 91,39 km. The river originates in the Lokachyn administrative district near the Kolpytiv village, in the upper reaches from east to west, and the middle and lower reaches - to the northwest. Near the Ustyluh town, Volodymyr-Volynskyi administrative district, 569 km from the mouth, it flows into the Western Bug river. The main tributaries of the Luha river: the rivers Svinoryyka, Rylovytsia, Strypa, a stream without a name from the Kolona village [16, 18]. Valleys with gentle slopes, width 0,2 – 0,8 km, height 6 - 8 m. The density of the river network in the river basin is 0,2 km / km2, the coefficient of meandering of the river is 1,7, the slope is 0,44 m / km. The floodplain of the river is the meadow, in some places it is bushy, its width increases with the length of the river by an average of 0,4 – 0,8 km. The average height of the floodplain above the river edge is 0,6 – 0,7 m, the banks are low, sloping, the bottom is flat, loamy, the channel is very winding. From the source to the Stary Porytsk village width does not exceed 5 m, depth – 1,5 m. To the Ivanivka village river width - 5 - 12 m, depth - up to 3 m, near the village expands to 16 - 29 m, depth - up to 3,5 m. Between the Ivanivka village and Volodymyr-Volynskyi city, the river is 10-25 m. wide and 0,4-1,5 m. deep. In the area of the Selets village of the river branches into branches, forming an island of considerable size (more than 150 hectares). Between Ustyluh town and Volodymyr-Volynskyi city there are many ridges and islands [16, 18]. The pool has a drainage system - Luhivska. The riverbed is canalized, the river floodplain is mowed and grazed by cattle almost to the water's edge, the territory of the basin has a high degree of plowing and is densely populated [16,18].

The Studyanka River is also a right tributary of the first order of the Western Bug. It originates in Ivanychiv district near the Hrybovytsia village and flows into the Western Bug south of the Ustyluh town, Volodymyr-Volynskyi district, 570 km from its mouth. The catchment area is 136 km2, the length is 26,5 km, the slope is 1,32 m / km. The density of the river network in the river basin is 0.27 km / km2, the meandering coefficient of the river is 1,37. The channel is winding, partially straight, the shores are low, sloping, the valley is located among the hilly terrain, the floodplain is covered with meadow vegetation. The width of the floodplain is 400 m, covered with meadow vegetation, the valley is located in the middle of hilly terrain. The territory of the basin is densely populated, plowed, there are trampling and mowing of floodplains, as well as the significant anthropogenic impact of the mining and industrial complex, as here are part of the existing and preserved mines of the Lviv-Volyn coal basin and heaps. In the pool, there are drainage systems - Yagidnivska, Izivska, Bugska [16,18].

Ecological and geobotanical studies in the Western Bug basin, within the test sections of the Luha and Studyanka riverbeds, were conducted during May-September 2019. 3 test sites were selected, at least 100 m long, located in the upper and lower reaches of the rivers. Peculiarities of distribution, species composition of indicator species of macrophytes, determined by the Chorna H. A. atlas [24] and projective coverage of each species in the test plots are shown in Table 2.

According to the results of the study, 17 species of macrophytes are common in both studied areas of the Luha River, which is 41,46% of the total number identified: *Equisetum palustre* L., *Nuphar lutea* (L.) *Smith*, *Polygonum hydropiper* L., *Myosotis palustris* (L.), *Bidens tripartita* L., *Alisma plantago-aquatika* L., *Sagittaria sagittifolia* L., *Hydrocharis morsus-ranae* L., *Stratiotes aloides* L., *Potamogeton natans* L., *Carex acutiformis Ehrh*., *Carex riparia Curtis*, *Phalaroides arundinacea* (L.) Rausch*., Phragmites australis* (Cav.), *Lemna minor* L., *Lemna trisulca* L., *Spirodela polyrrhiza* (L.) *Schleid*.

On the test site № 1 Zavydiv village, 18 species of macrophytes were found in the river basin, but are absent here: *Thelypteris palustris* Schott, *Nymphaea alba* L., *Myriophyllum verticillatum* L., *Myriophyllum spicatum* L., *Ceratophyllum demersum* L., *Ceratophyllum submersum* L., *Cicutaro* L., *Lysimachia vulgaris* L., *Rorippa amphibia (*L.) Bess, *Mentha aquatica* L., *Potamogeton acutifolius* Link., *Potamogeton lucens* L., *Carex acuta* L., *Scirpus sylvaticus* L., *Scirpus lacustris* L., *Glyceria maxima* (C . Hartm.), *Tupha latifolia* L., *Typha angustifolia* L. At the test site № 2 Volodymyr-Volynskyi city downstream, 6 species of macrophytes were found, which are characteristic of the river basin, but are absent in this experimental area *Spach*, *Polygonum amphibium* L., *Potamogeton crispus* L., *Iris pseudacorus* L., *Acorus calamus* L., *Sparganium erectum* L.

The largest group of macrophyte species in the Luha riverbed is the coastal air-water vegetation - 24 species (58,54%), which is reflected in Fig. 1. These are representatives of 16 families - *Equisetaceae, Thelypteridaceae, Alismataceae, Iridaceae, Cyperaceae, Poaceae, Acoraceae, Sparganiaceae, Typhaceae, Polygonaceae, Apiaceae, Primulaceae, Brassicaeae, Boraginaceae*. Plants with floating leaves - 10 species (24,39%), belong to 6 families - *Hydrocharitaceae, Potamogetonaceae, Lemnaceae, Numphaeaceae, Ranunculaceae, Polygonaceae*. Another 7 species (17,07%) - submerged plants belonging to 4 families - *Hydrocharitaceae, Potamogetonaceae, Haloragaceae, Ceratophyllaceae*.

According to the study, the flora of the Studyanka River includes 19 species of aquatic and air-aquatic plants belonging to 2 divisions (*Equisetophyta* and *Magnoliophyta*), 12 families, and 15 genera (Table 2). One species belongs to the Equisetophyta division (5,3%), and eighteen species

Table 2

Species composition and projective coverage (P) of indicator species of macrophytes within the test areas of the Luha, Studyanka riverbed

№	Type of macrophyte	Test area								
		№ 1	P		№ 2	P		№ 3	P	
			%	Coefficient		%	Coef-ficient		%	Coef-ficient
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Class Equisetopsida										
1.	*Equisetum palustre* L.	+	2	3	+	2	3	+	2	3
Class Polypodiopsida										
2.	*Thelypteris palustris* Schott	-			+	7	5			
Class Magnoliopsida										
3.	*Nymphaea alba* L.	-			+	2	3	-	5	3
4.	*Nuphar lutea* (L.) Smith	+	7	5	+	6	5	+	5	5
5.	*Batrachium circinatum* (Sibth.) Spach	+	4	4	-					
6.	*Polygonum amphibium* L.	+	4	4	-			+		
7.	*Polygonum hydropiper* L.	+	5	5	+			-		
8.	*Myriophyllum verticillatum* L.	-			+	7	5	-		
9.	*Myriophyllum spicatum* L.	-			+	6	5	-		
10.	*Ceratophyllum demersum* L.	-			+	8	5	+	10	5
11.	*Ceratophyllum submersum* L.	-			+	7	5	+		
12.	*Cicuta virosa* L.	-			+	3	4	-		
13.	*Lysimachia vulgaris* L.	-			+	5	5	-		
14.	*Rorippa amphibia* (L.) Bess	-			+	4	4	-		
15.	*Myosotis palustris* (L.)	+	2	3	+	3	4	+		
16.	*Mentha aquatica* L.	-			+	7	5	+	6	5
17.	*Bidens tripartita* L.	+	4	4	+	5	5	-		
Class Liliopsida										
18.	*Alisma plantago-aquatika* L.	+	5	5	+	5	5	-		
19.	*Sagittaria sagittifolia* L.	+	7	5	+	10	6	-		
20.	*Hydrocharis morsus-ranae* L.	+	10	6	+	10	6	+	12	6
21.	*Stratiotes aloides* L.	+	10	6	+	10	6	+	12	6
22.	*Potamogeton acutifolius* Link.	-			+	1	2	-		
23.	*Potamogeton crispus* L.	+	6	5	-			-		
24.	*Potamogeton lucens* L.	-			+	2	3	+	8	5
25.	*Potamogeton natans* L.	+	6	5	+	6	5	+	7	5
26.	*Iris pseudacorus* L.	+	2	3	-			-		
27.	*Carex acuta* L.	-			+	10	6	+	7	5
28.	*Carex acutiformis* Ehrh.	+	7	5	+	7	5	+		
29.	*Carex riparia* Curtis.	+	6	5	+	6	5	+	8	5
30.	*Scirpus sylvaticus* L.	-			+	7	5	-		
31.	*Scirpus lacustris* L.	-			+	6	5	-		
32.	*Phalaroides arundinacea* (L.) *Rausch.*	+	6	5	+	7	5	+		
33.	*Glyceria maxima* (C. Hartm.)	-			+	10	6	-		
34.	*Phragmites australis* (Cav.)	+	15	6	+	10	6	+	8	5
35.	*Acorus calamus* L.	+	5	5	-			+		
36.	*Lemna minor* L.	+	10	6	+	10	6	-		
37.	*Lemna trisulca* L.	+	7	5	+	6	5	-		
38.	*Spirodela polyrrhiza* (L.) Schleid	+	6	5	+	7	5	-		
39.	*Sparganium erectum* L.	+	6	5	-			-		
40.	*Tupha latifolia L.*	-			+	7	5	+	7	5
41.	*Typha angustifolia* L.	-			+	6	5	+	8	5

(94,7%) belong to the *Magnoliophyta* division. The class of monocotyledonous plants is represented by 6 families, 8 genera, and 11 species (57,9% of the total number of species). The class of dicotyledonous plants is represented by 5 families, 6 genera, and 7 species (36,8% of the total number of species). The largest number of species contain the family *Cyperaceae* (3 – 15,8%). Other families are represented by one or two species (84,2% of the total number of families).

The largest group of plants is coastal air-water vegetation - 12 species (63,2%). These are representatives of 7 families - *Equisetaceae, Cyperaceae, Poaceae, Acoraceae, Typhaceae, Boraginaceae, Lamiaceae*.

Plants with floating leaves 4 species (15,8%) belong to 4 families - *Hydrocharitaceae, Potamogetonaceae, Numphaeaceae, Polygonaceae*. Another 3 species (15,8%) are submerged plants belonging to 2 families - *Hydrocharitaceae* and *Ceratophyllaceae*.

During the research within the test area № 1 (Zavydiv village) of the riverbed, 23 species of macrophytes were found - indicators of the ecological status of river water (Table 2). They are dominated by coastal plants and plants with floating leaves.

Study of the ecological condition of river water at the test site № 2 (Volodymyr-Volynskyi city), 35 species of macrophytes were found - indicators of the ecological condition of river water (Table 2). Here are presented relatively evenly all ecological groups of plants - coastal, submerged, and with floating leaves.

Investigating the ecological status of the Studyanka river water at the test site № 3 (Ustyluh town), 19 species of macrophytes were found - indicators of the ecological status of river water (Table 2). They are dominated by coastal plants, 4 species of plants with floating leaves, and 3 species of submerged plants.

According to the results of the study, the ecological status of the Luha and Studyanka rivers was assessed according to the Macrophyte Index for Rivers (MIR). To calculate the MIR, the formula shown above was used and the classification table for 4 types of rivers was used (Table 1).

In the Luha and Studyanka rivers, 41 indicator species of macrophytes were found in the surveyed areas, according to the Methodology, the characteristics of which were used to calculate the MIR value. For each species of macrophytes, the quantitative value of the indicator (**L**), weighting factor (**W**), (Table 3), projective coverage (%), and coverage ratio (**P**) on a 9 - point scale were determined, which is shown in Table 1.

The results shown in the table show that 41 indicator species of macrophytes have been identified in the Luha riverbed, the quantitative value of macrophyte indicators varies between 2 - 6 and the weight coefficient - from 1 to 3.

Table 3

Indicator species of macrophytes [4, 25]

Class / Plant	**MIR**		**Class / Plant**	**MIR**		**Class / Plant**	**MIR**	
	L	**W**		**L**	**W**		**L**	**W**
Equisetopsida			*Nuphar lutea* L.			*Lemna minor* L.	2	2
Equisetum palustre L.	5	2	*Polygonum amphibium* L.	4	1	*Lemna trisulca* L.	4	2
Polypodiopsida			*Polygonum hydropiper* L.	3	1	*Phragmites australis*	4	2
Thelypteris palustris Schott	6	1	*Batrachium circinatum* (Sibth.) Spach	5	2	*Potamogeton acutifolius* Link.	6	1
Magnoliopsida			*Rorippa amphibia* L.	3	1	*Potamogeton crispus* L.	4	2
Bidens tripartita L.	2	3	**Liliopsida**			*Potamogeton lucens* L.	4	3
Ceratophyllum demersum L.	2	3	*Acorus calamus* L.	2	3	*Potamogeton natans* L.	4	1
Ceratophyllum submersum L.	2	3	*Alisma plantago-aquatica* L.	4	2	*Sagittaria sagittifolia* L.	4	2
Cicuta virosa L.	6	2	*Carex acuta* L.	5	1	*Scirpus lacustris* L.	4	2
Lysimachia vulgaris L.	4	1	*Carex acutiformis* Ehrh	4	1	*Scirpus sylvaticus* L.	5	2
Mentha aquatica L.	5	1	*Carex riparia* Curtis	4	2	*Sparganium erectum* L.	3	1
Myosotis palustris (L.) L.J.	4	1	*Phalaroides arundinacea* (L.) Rausch.	2	1	*Spirodela polyrrhiza* (L.)Schleid.	2	2
Myriopfyllum spicatum L.	3	2	*Glyceria maxima* (C. Hartm.)	3	1	*Stratiotes aloides* L.	6	2
Myriophyllym verticillatum L.	5	2	*Hydrocharis morsus-ranae* L.	6	2	*Typha angustifolia* L.	3	2
Numphaea alba L.	6	2	*Iris pseudacorus* L.	6	2	*Typha latifolia* L.	2	2

The results of calculations of the Macrophyte Index for Rivers showed the following:

MIR (test area 1) =

$$\sum (L_i \times W_i \times P_i) / \sum (W_i \times P_i) \times 10 = 39{,}0$$

MIR (test area 2) =

$$\sum (L_i \times W_i \times P_i) / \sum (W_i \times P_i) \times 10 = 31{,}56$$

MIR (test area 3) =

$$\sum (L_i \times W_i \times P_i) / \sum (Wi \times P_i) \times 10 = 28{,}31$$

According to the classification of the indicator MIR [23] to determine the ecological status of the rivers Luha and Studyanka belong to the lowland watercourses, with the type of macrophytes - M-VIII (organic rivers). As a result of the calculated Macrophyte Index for Rivers (MIR), it was established (Table 4) that the water quality in the Luha River in test site 1 (Zavydiv village) has a good ecological status and MIR is 39,0; and on test site 2 (Volodymyr-Volynskyi city) has a satisfactory or moderate ecological condition and MIR is 31,56; in the river Studyanka, on the test site 3 (Ustyluh town) has a satisfactory or moderate ecological condition and MIR is 28,31.

Table 4

Ecological condition of Luha and Studyanka rivers according to MIR index

Test site of the riverbed	Index MIR	Ecological condition
1. Zavydiv village (upper course)	39,0	Good
2. Volodymyr-Volynskyi (lower reaches)	31,56	Satisfactory or moderate
3. Ustyluh town	28,31	Satisfactory or moderate

During the research at all test sites, violations of water protection legislation and partial use of the river water protection zone for economic purposes (availability of farm buildings and agricultural lands) were also revealed; ingress into surface waters of residential and commercial facilities (cesspools), clogging of the riverbed, and in the basin of the river Studyanka, also, there is man-made relief (subsidence of the relief over the mine workings, the presence of waste heaps and dumps).

To determine a more objective assessment of the ecological status of river water, a comparison of hydrochemical indicators of surface water quality (the results of laboratory studies of surface waters of the rivers Luha and Studyanka performed by the instrumental laboratory control department of the State Ecological Inspectorate in Volyn region for 2019 were used) and Macrophyte Index for Rivers (MIR) as well as assessment of the ecological condition of the rivers Luha and Studyanka was performed.

Based on the analysis of surface water quality on the basis of hydrochemical parameters, it can be stated that the values of mineralization values for both observation points of the Luha and Studyanka rivers were fresh hypohaline. According to the components of the salt composition, their waters belonged to category 1 of class I ("excellent" in their natural state, "very pure" in the degree of its purity). The average values of hydrochemical parameters and blocks of trophosaprobiological and specific substances of toxic action included the waters of the Luha River to 4 and 5 categories of water quality class III ("satisfactory" in their natural state, "polluted" in purity), and the waters of the river Studyanka 5 category III water quality class ("satisfactory" in their natural state and "contaminated" in the degree of purity). In general, the average annual values of hydrochemical parameters of both observation points classified the waters of the Luha river into 4 categories ("quite good" in their natural state, "slightly polluted" in the degree of purity) of the third class of water quality ("satisfactory" in their natural state and "moderately polluted" by the degree of purity, the level of trophic - eutrophic). The waters of the Studyanka River up to the 5th category ("satisfactory" in their natural state, "moderately polluted" in the degree of purity) of the III class of water quality ("satisfactory" in their natural state, "moderately polluted" in the degree of purity, the level of trophism - eutrophic) .

It is determined that the ecological condition of the river according to the average annual values of hydrochemical indicators included the waters of the Luha River (in Volodymyr-Volynskyi city) to the 4th category of class III water quality ("satisfactory" in their natural state, "polluted" in the degree of purity), and water of the river Studyanka up to the 5th category of the III class of water quality ("satisfactory" in their natural state, "moderately polluted" in the degree of purity, the level of trophic - eutrophic).

According to the ecological status of rivers determined by the Macrophyte Index for Rivers (MIR), it is established that the waters of the Luha and Studyanka rivers have a satisfactory or moderate ecological status. This suggests that the research conducted on test sites and calculations of the Macrophyte Index for Rivers (MIR) are identical and fully reflect the ecological status of the rivers Luha and Studyanka determined by hydrochemical parameters, which allows using this algorithm for other rivers in the Western Bug basin.

Conclusions. Based on the research, the following conclusions can be drawn:

1. A significant part of the water management complex of the Volyn region is the basin of the

Western Bug river, which has a significant degree of development. Also, the state border between Ukraine and Poland runs along the watercourse, the river is a cross-border, and the tributary basins are located on the territory of both states. Therefore, to restore and preserve the optimal ecological condition of the Western Bug river basin, it is necessary to adhere to the strategic principles of rational nature management, within the catchments of small rivers.

2. To assess the ecological status of the MIR index *(Macrophyte Index for Rivers)*, 42 indicator species of macrophytes were selected, of which 1 species belongs to the division *Polipodiophyta* and *Equisetopsida*, 40 species to the division *Magnoliophyta*, of which 15 belong to the class *Magnoliopsida*, and 25 belong to the class *Liliopsida*.

3. During the research within the test area № 1 (Zavydiv village) of the riverbed, 23 species of macrophytes were found - indicators of the ecological status of river water. They are dominated by coastal plants and plants with floating leaves. Study of the ecological condition of river water at the test site № 2 (Volodymyr-Volynskyi city), 35 species of macrophytes were found - indicators of the ecological condition of river water. Here we see relatively evenly all ecological groups of plants - coastal, submerged, and with floating leaves. Investigating the ecological state of the Studyanka river water at the test site № 3 (Ustyluh town), 19 species of macrophytes were found - indicators of the ecological state of the river water. They are dominated by coastal plants, 4 species of plants with floating leaves, and 3 species of submerged plants.

4. As a result of determining the ecological status of the tributaries of the Western Bug river, according to the MIR indicator, it was established that the rivers Luha and Studyanka belong to lowland watercourses, with the type of macrophytes - M-VIII (organic rivers). As a result of the calculated Macrophyte Index for Rivers (MIR) it was found that the water quality in the Luha River at test site 1 (Zavydiv village) has a good ecological status and MIR is 39,0; on test site 2 (Volodymyr-Volynskyi city) has a satisfactory or moderate ecological condition and MIR is 31,56. The water quality in the Studyanka River in test site 3 (Ustyluh town) has a satisfactory or moderate ecological status and MIR is 28,31.

5. To obtain a more objective assessment of the ecological status of river water, a comparison of hydrochemical indicators of surface water quality and the results of determining the ecological status of rivers according to the Macrophyte Index for Rivers (MIR) will be carried out. It is determined that the ecological condition of the river according to the average annual values of hydrochemical indicators included the waters of the Luha River (in Volodymyr-Volynskyi city) to the 4th category of class III water quality ("satisfactory" in their natural state, "polluted" by the degree of purity) water of the river Studyanka up to the 5th category of the III class of water quality ("satisfactory" in their natural state, "moderately polluted" by the degree of purity, the level of trophic - eutrophic).

According to the ecological status of rivers determined by the Macrophyte Index for Rivers (MIR), it is established that the waters of the Luha and Studyanka rivers have a satisfactory or moderate ecological condition. This suggests that the research conducted on test sites and calculations of the Macrophyte Index for Rivers (MIR) are identical and fully reflect the ecological status of the rivers Luha and Studyanka determined by hydrochemical parameters, which allows the use of this research algorithm for other rivers in the Western Bug river basin and is promising during research on other rivers of Ukraine.

Bibliography

1. *Боярин М. В. Основи гідроекології: теорія й практика. Навчальний посібник. [Текст] / М. В. Боярин, І. М Нетробчук. – Луцьк: Вежа–Друк, 2016. – 364 с.*
2. *Zueva N. V. Use of Macrophytes in Assessing the Ecological Status of Small River (by the Example of the Okhta River, St. Petersburg) / N. V. Zueva, A. A. Bobrov // Inland Water Biology. – 2018. – Volume 11. – P. 34–41. https://doi.org/10.1134/S1995082917040137*
3. *Клименко М. О. Оцінка екологічного стану водних екосистем річок басейну Припяті за вищими рослинами : монографія. [Текст] / О. М. Клименко, Ю.Р. Гроховська. – Рівне : НУВГП, 2005. – 194 с.*
4. *Коробкова Г. В. Використання макрофітних індексів для оцінки екологічного стану поверхневих вод України / Г. В. Коробкова // Людина та довкілля. Проблеми неоекології. – 2017. – № 1–2 (27). – С. 62–70.*
5. *Muratov R. An attempt to prepare Macrophyte Index for Rivers for assessment watercourses in Kazakhstan // Muratov, R.; Szoszkiewicz, K.; Zhamangara, A.; Jusik, S.; Gebler, D.; Beisenova, R.; Akbayeva, L. // Meteorol. Hydrol. Water Manage. – 2015. – 2. – № 3. – P. 27–32. https://doi.org/10.26491/mhwm/59592*
6. *Marcinkowski P. Model-Based Analysis of Macrophytes Role in the Flow Distribution in the Anastomosing River System / Marcinkowski, P., Kiczko, A., Okruszko, T. // Water. – 2018. – №10. – 953 p. https://doi.org/10.3390/w10070953*
7. *Методи гідроекологічних досліджень поверхневих вод [Текст] / Арсен О. М. та ін.; під ред. В. Д. Романенка. – К. : ЛОГОС, 2006. – 408 с.*
8. *Макрофиты-индикатори изменений природной среды [Текст] . – Київ : Наукова думка, 1993. – 434 с.*

9. *Нетробчук І.М. Геоекологічний стан басейну річки Луга / І. М . Нетробчук // Наук. вісник ВНУ ім. Лесі Українки. Географічні науки. – Луцьк: Волин. нац. ун-т. ім. Лесі Українки. – 2010. – № 9 . – С. 176–182.*
10. *Некос А. Н., Боярин М. В. Управління водними ресурсами в басейні ріки Західний Буг на Волині. Науковий вісник Волинського державного університету ім. Лесі Українки. Географічні науки. – Луцьк. – 2009.– № 8. – С. 8 – 11.*
11. *Перхач О. В. Екологічна ситуація басейну р. Луга Волинської області / О. Перхач, Ф. Кіптач, М. Сиротюк // Наукові записки ТНПУ. – 2016. – № 1. – С. 222–229.*
12. *Романенко В. Д. Методика екологічної оцінки якості поверхневих вод за відповідними категоріями [Текст] / В. Д. Романенко, В. М. Жукинський, О. П. Оксіюк. – К.: Символ – Т, 1998. – 28 с.*
13. *Савицкая К. Л. Оценка экологического состояния малых рек на основе биологического индекса макрофитов. / К. Л. Савицкая // Вестник БГУ. Сер. 2. – 2014. – № 3. – С. 22–27.*
14. *Фесюк В. О. Вплив водогосподарського комплексу м. Володимир-Волинський на екологічний стан р. Луга / В. О. Фесюк, Б. С. Кротач // Вісник Кам'янець-Подільського національного університету імені Івана Огієнка. Серія: Екологія. – 2018. – № 3. – С. 213–226.*
15. *Яцик А. В. Екологічна оцінка якості основних річкових басейнів Волинської області / А. В. Яцик, І. В. Гопчак // Водне господарство України. – 2005. – №5. – С. 13–17.*
16. *Яцик. А. В. Екологічна оцінка сучасного стану якості води річки Луга./ А. В. Яцик, І. А. Пашенюк, І. В. Гопчак, Т. О. Басюк // Вісник аграрної науки. – 2019. – № 2. – С. 61–65. https://doi.org/10.31073/agrovisnyk201902-08*
17. *Jusik, S. Development of comprehensive river typology based on macrophytes in the mountain-lowland gradient of different Central European ecoregions. // Jusik, S., Szoszkiewicz, K., Kupiec, J. Hydrobiologia. – 2015. – № 745. – P. 241–262. https://doi.org/10.1007/s10750-014-2111-2*
18. *Сучасний екологічний стан та перспективи екологічно безпечного стійкого розвитку Волинської області. За ред. В. О. Фесюка. [Текст]. – К. : ТОВ «Підприємство ВІ ЕН ЕЙ», 2016. – 316 с.*
19. *Регіональна доповідь про стан навколишнього природного середовища у Волинській області у 2018 році. Луцьк [б.в], 2019. – 196 с. URL: http://eco.voladm.gov.ua*
20. *Цьось О. О. Екологічна оцінка якості поверхневих вод річки Турія // О. О. Цьось / Природа Західного Полісся та прилеглих територій. – 2015. – №12. – С. 69–74.*
21. *Цьось О. О. Екологічна оцінка якості поверхневих вод річки Цир за категоріями. //О. О. Цьось / Людина та довкілля. Проблеми неоекології. – 2017. – № 1. –2 (27). – С. 71–76.*
22. *Цьось О. О. Структурний аналіз вищих водних та прибережно-водних рослин річки Вижівка // О. О. Цьось, О. С. Музиченко, М. В. Боярин / Людина та довкілля. Проблеми неоекології. – 2018. – № 30. – С. 104–111. https://doi.org/10.26565/1992-4224-2018-30-08*
23. *Цьось О. О. Індикаторна флора річки Турія // О. О. Цьось / Вісник Харківського університету імені В. Н. Каразіна. Серія «Екологія». – 2016. – № 14. – С. 71–77.*
24. *Чорна Г. А. Рослини наших водойм. [Текст] / Г. А. Чорна. – К. : Фітосоціоцентр, 2001. – 134 с.*
25. *Ciecierska H. Biologiczne metody oceny stanu srodowiska. Tom 2. Ekosystemy wodne. Podrecznik metodyczny / Hanna Ciecierska, Maria Dynowska. – Olsztyn. – 2013. – 312 p.*
26. *AFNOR (Assosiation Francaise de Normalisation) Qualite de l'eau – Determination de l'indice biologique macropfytique en rivier (IBMR) – Norm francaise NFT, 2003. – P. 90–395.*
27. *Szoszkiewicz K. An Assessment of the MTR Aquatic Plant Bioindication System for Determining the Trophic Status of Polish Rivers // Szoszkiewicz K., Karolewicz K., Lawniczak A., Dawson F. Polish Journal of Environmental Studies. – Vol. 11. – № 4 (2002). – P. 421–427.*
28. *Szoszkiewicz K. The Macrophyte Index for Rivers (MIR) asan Advantageous Approach to Running Water // Szoszkiewicz K., Jusik S., Pietruczuk K., Gebler D. Assessment in Local Geographical Conditions Water. – 2020. – № 12. – P. 108. https://doi.org/10.3390/w12010108*
29. *Szoszkiewicz, K. Metodyka Bada´n Terenowych Makrofitów na Potrzeby Rutynowego Monitoringu Rzek / Szoszkiewicz, K., Zbierska, J., Jusik, S., Zgola, T. Bogucki Wydawnictwo Naukowe: Poznan, Poland. – 2009. – 81 p.*
30. *Szoszkiewicz, K. The variability of macrophyte metrics used in river monitoring. // Szoszkiewicz, K., Zbierska, J., Staniszewski, R., Jusik, S. Oceanol. Hydrobiol. Stud. – 2009. – № 38. – P. 117–126.*
31. *EU Water Framework Directive 2000/60/EC. Official Journal of the European Communities, 22.12.2000. L 327 / 1. – 118 p.*
32. *Mariia Boiaryn. Ocena stanu ekologicznego powierzchniowych wód rzeki Turia na podstawie makrofitowego indeksu rzecznego (MIR) // Mariia Boiaryn, Oksana Tsos. – Chemia. Envirinment. Biotechnology. – 2019. – № 22. – P. 7–12. www.ceb-journal.com, http://dx.doi.org/10.16926/cebj.2019.22.01*
33. *Удосконалена схема фізико-географічного районування України / О.М. Маринич, Г.О. Пархоменко, О.М. Петренко, П.Г. Шищенко // Український географічний журнал. – 2003. – № 1. – С. 16–20.*

Submitted November 07, 2020
Accepted March 10, 2021

***Authors Contribution**: All authors have contributed equally to this work.*

UDC 556.51:502.51(477)

Alla Nekos,
DSc (Geography), Professor, Head of the Department of Ecological Safety and Ecological Education
Karazin Institute of environmental sciences, V. N. Karazin Kharkiv National University,
4 Svobody Sq., Kharkiv, 61022, Ukraine,
e-mail: alnekos999@gmail.com, http://orcid.org/0000-0003-1852-0234;
Mariia Boiaryn,
PhD (Geography), Associate Professor, Department of Ecology and Environmental Protection,
Lesya Ukrainka Volyn National University, 13 Voli Ave., Lutsk, 43025, Ukraine,
e-mail: mariasun140314@gmail.com, http://orcid.org/0000-0001-9822-5897;
Maria Lugowska,
Dr. Eng., Assistant Professor at the Institute of Agriculture and Horticulture,
University of Natural Sciences and Humanities, Prusa St., 14, 08-110 Siedlce, Poland,
e-mail: maria.lugowska@uph.edu.pl, http://orcid.org/0000-0001-5284-7965;
Oksana Tsos,
Lecturer, Department of Ecology and Environmental Protection,
Lesya Ukrainka Volyn National University,
e-mail: oksana.tsos1972@gmail.com, http://orcid.org/0000-0002-9679-9413;
Iryna Netrobchuk,
PhD (Geography), Associate Professor, Department of Geography,
Lesya Ukrainka Volyn National University,
mail: iryna.nim@gmail.com https://orcid.org/0000-0002-8633-7426

ASSESSMENT OF THE ECOLOGICAL CONDITION OF THE WESTERN BUG RIVER BASIN ACCORDING TO THE MACROPHYTE INDEX FOR RIVERS (MIR)

Introduction. To restore and preserve the optimal ecological status of the Western Bug river basin, it is necessary to adhere to the strategic principles of environmental management, and since the river is transboundary and tributary basins are located in Ukraine and Poland, it is important to determine the ecological status of small rivers. In the territory of the Volyn region, the rivers-tributaries Luha and Studyanka are most affected by anthropogenic impact. An ecological assessment of water quality based on the condition of macrophytes is given, as macrophytes llow to determine the degree of surface water degradation, first of all, in terms of their trophic status.

The purpose of article. The purpose of article aims to assess the ecological status of the rivers of the Western Bug river basin using bioindication methods and determination of the Macrophyte Index for Rivers (MIR).

Methods. Research methods are expeditionary, methods of mathematical statistics end bioindication methods and determination of the Macrophyte Index for Rivers (MIR).

Results. To determine the ecological status of the rivers of the Western Bug basin and to conduct research, three test sites with a length of at least 100 m were laid on two tributaries of the first order - the rivers Luha and Studyanka. To determine the MIR (*Macrophyte Index for Rivers*) in the test riverbed areas, 42 indicator species of macrophytes were selected, of which 1 species belongs to the division Polipodiophyta and Equisetophyta, 40 species to the division Magnoliophyta, of which 15 belong to the class Magnoliopsida, and 25 belong to the class Liliopsida. According to the classification of the MIR indicator, to determine the ecological status, the rivers Luha and Studyanka belong to lowland watercourses, with the type of macrophytes - M-VIII (organic rivers). As a result of the calculated Macrophyte Index for Rivers (MIR), it was established (Table 4) that the water quality in the Luha river in test site 1 (Zavydiv village) has a good ecological status, MIR is 39,0; and test site 2 (Volodymyr-Volynskyi city) has a satisfactory or moderate ecological status, MIR is 31,56; in the river Studyanka, the test site 3 (Ustyluh town) has a satisfactory or moderate ecological condition, MIR is 28,31.

Conclusions. According to the ecological status of rivers determined by the Macrophyte Index for Rivers (MIR), it is established that the waters of the Luha and Studyanka rivers have a satisfactory or moderate ecological condition. This suggests that the research conducted on test sites and calculations of the Macrophyte Index for Rivers (MIR) are identical and fully reflect the ecological status of the rivers Luha and Studyanka determined by hydrochemical parameters, which allows the use of this research algorithm for other rivers in the Western Bug river basin and is promising during research on other rivers of Ukraine.

Keywords: river, bioindication, macrophytes, ecological condition of rivers, macrophyte index, water quality classes, ecological assessment of water quality.

References

1. *Boyaryn M. V., Netrobchuk I. M. (2016). Fundamentals of hydroecology: theory and practice. Tutorial. Lutsk: Tower – Print, 364 [in Ukrainian].*
2. *Zueva N. V., Bobrov A. A. (2018). Use of Macrophytes in Assessing the Ecological Status of Small River (by the Example of the Okhta River, St. Petersburg). Inland Water Biology. Volume 11, 34–41. https://doi.org/10.1134/S1995082917040137 [in Russian].*
3. *Klymenko M. O., Grokhovska Yu. R. (2005). Estimation of ecological condition of water ecosystems of rivers of the Pripyat basin by higher plants. Rivne. NYVGP, 194 [in Ukrainian].*
4. *Korobkova G. V. (2017). Use of macrophytic indices to assess the ecological status of surface waters of Ukraine. Man and the environment. Problems of Neoecology. 1–2(27), 62-70 [in Ukrainian].*
5. *Muratov, R.; Szoszkiewicz, K.; Zhamangara, A.; Jusik, S.; Gebler, D.; Beisenova, R.; Akbayeva, L. (2015). An attempt to prepare Macrophyte Index for Rivers for assessment watercourses in Kazakhstan. Meteorol. Hydrol. Water Manage. 3, 27–32 https://doi.org/10.26491/mhwm/59592 [in Polish].*
6. *Marcinkowski, P., Kiczko, A., Okruszko, T. (2018). Model-Based Analysis of Macrophytes Role in the Flow Distribution in the Anastomosing River System. Water, 10, 953. https://doi.org/10.3390/w10070953 [in English]*
7. *Arsen O. M., Romanenko V. D. (2006). Methods of hydroecological research of surface waters. K. , LOGOS, 408 [in Ukrainian].*
8. *Macrophytes are indicators of changes in the natural environment, (1993). Kyiv, Naukova Dumka, 434 [in Ukrainian].*
9. *Netrobchuk I. M. (2011). Geoecological condition of the Luha river basin. Lutsk. Science. Bulletin of the University. Lesya Ukrainka. Geographical sciences. Lutsk: Volyn. nat. un-t. them. Lesya Ukrainka. 9, 176-182 [in Ukrainian].*
10. *Nekos A. N., Boyaryn M. V. (2009). Management of water resources in the Western Bug river basin in Volyn. Lutsk. Science. Bulletin of the University. Lesya Ukrainka. Geographical sciences. Lutsk: Volyn. nat. un-t. them. Lesya Ukrainka. 8, 8–11 [in Ukrainian].*
11. *Perhach O. V., Kiptach F., Syrotiuk M. (2016). Ecological situation of the Luha river basin of Volyn region. Scientific notes of TNPU. 1, 222–229 [in Ukrainian].*
12. *Romanenko V. D., Zhukinsky V. M., Oksiyuk O. P. (1998). Methods of ecological assessment of surface water quality by appropriate categories. K., Symbol, 28 [in Ukrainian].*
13. *Savitskaya K. L. (2014). Estimation of ecological condition of small rivers on the basis of biological index of macrophytes. Bulletin of BSU. Ser. 2, 22–27 [in Ukrainian].*
14. *Fesyuk V. O., Krotach B. S. (2018). Influence of the water management complex of Volodymyr-Volynskyi on the ecological condition of the Luha River. Bulletin of Kamyanets-Podilsky National University named after Ivan Ogienko. Series "Ecology". 3, 213–226. [in Ukrainian].*
15. *Yatsyk A. V., Hopchak I. V. (2005). Ecological assessment of the quality of the main river basins of the Volyn region. Water management of Ukraine. 5, 13–17. [in Ukrainian].*
16. *Yatsyk A. V., Pashenyuk I. A., Hopchak I. V., Basyuk T. O. (2019) Ecological assessment of the current state of water quality of the Luha River. Bulletin of Agricultural Science, 2, 61–65 [in Ukrainian]. https://doi.org/10.31073/agrovisnyk201902-08*
17. *Jusik, S., Szoszkiewicz, K., Kupiec, J. (2015). Development of comprehensive river typology based on macrophytes in the mountain-lowland gradient of different Central European ecoregions. Hydrobiologia, 745, 241–262 [in English] https://doi.org/10.1007/s10750-014-2111-2*
18. *Fesyuk V. O. (2016). Current ecological condition and prospects of ecologically safe sustainable development of Volyn region. K ., VAN Enterprise Enterprise LLC. 316 [in Ukrainian].*
19. *Regional report on the state of the environment in the Volyn region in 2018 (2019). Lutsk, 196. URL: http://eco.voladm.gov.ua [in Ukrainian].*
20. *Tsyos O. O., (2015). Ecological assessment of surface water quality of Turia river. Nature of Western Polissya and adjacent territories, 12, 69–74 [in Ukrainian].*
21. *Tsyos O. O. (2017). Ecological assessment of surface water quality of the river Tsyr by categories. Man and the environment. Problems of neoecology, 1–2 (27), 71–76 [in Ukrainian].*
22. *Tsyos O. O., Muzychenko O. S., Boyaryn M. V. (2018). Structural analysis of higher aquatic and coastal aquatic plants of the Vyzhivka river. Man and the environment. Problems of Neoecology, 30, 104–111. [In Ukrainian] https://doi.org/10.26565/1992-4224-2018-30-08*
23. *Tsyos O. O. (2016). Indicator flora of the river Turia. Bulletin of V. N Karazin Kharkiv University. Series "Ecology", 14, 71–77 [in Ukrainian].*
24. *Chorna H.A. (2001). Plants of our reservoirs, 134 [in Ukrainian].*
25. *Hanna Ciecierska, Maria Dynowska (2013) Biological methods of assessing the state of the environment. Volume 2. Water ecosystems. Methodical handbook. Olsztyn, 312 [in Polish].*
26. *AFNOR (Assosiation Francaise de Normalisation) Qualite de l'eau – Determination de l'indice biologique macropfytique en rivier (IBMR) – Norm francaise NFT (2003), 9–395 [in French]*

27. *Szoszkiewicz K., Karolewicz K., Lawniczak A., Dawson F. (2002) An Assessment of the MTR Aquatic Plant Bioindication System for Determining the Trophic Status of Polish Rivers. Polish Journal of Environmental Studies. 11, 4, 421–429 [in Polish].*
28. *Szoszkiewicz K., Jusik S., Pietruczuk K., Gebler D. (2020). The Macrophyte Index for Rivers (MIR) asan Advantageous Approach to Running Water. Assessment in Local Geographical Conditions. Water, 12, 108 [in English] https://doi.org/10.3390/w12010108*
29. *Szoszkiewicz, K.; Zbierska, J.; Jusik, S.; Zgola, T. (2009). Metodyka Bada´n Terenowych Makrofitów na Potrzeby Rutynowego Monitoringu Rzek [Macrophyte Survey Manual for the Purpose of River Monitoring]; Bogucki Wydawnictwo Naukowe: Poznan, Poland, 81 [in Polish].*
30. *Szoszkiewicz, K., Zbierska, J., Staniszewski, R., Jusik, S. (2009). The variability of macrophyte metrics used in river monitoring. Oceanol. Hydrobiol. Stud., 38, 117–126.*
31. *EU Water Framework Directive 2000/60/EC. Official Journal of the European Communities, 22.12.2000. L 327/1, 118.*
32. *Mariia Boiaryn, Oksana Tsos (2019). Assessment of the ecological status of the Turia River surface waters on the basis of the River Macrophyte Index (MIR). Chemistry. Envirinment. Biotechnology. 22, 7–12 [in Polish] www.ceb–journal.com, http://dx.doi.org/10.16926/cebj.2019.22.01*
33. *Marynych O. M., Parkhomenko H. O., Petrenko O. M., Shyshchenko P. H. (2003). Improved physical and geographical zoning of the Ukraine. Ukrainian geographical journal, 1, 16–20 [In Ukrainian].*