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ENVIRONMENTAL ASSESSMENT OF WATER QUALITY IN VARIOUS LAKES OF THE VOLYN REGION, WHICH IS INTENSIVELY USED IN RECREATION

В. О. Фесюк, Л. В. Ільїн, І. А. Мороз, О. В. Ільїна. ЕКОЛОГІЧНА ОЦІНКА ЯКОСТІ ВОДИ РІЗНОТИПНИХ ОЗЕР ВОЛИНСЬКОЇ ОБЛАСТІ, ЩО ІНТЕНСИВНО ВИКОРИСТОВУЮТЬСЯ В РЕКРЕАЦІЇ. *Озера Волинської області мають важливе природне і господарське значення. Узбережжя озер інтенсивно використовують у рекреаційній діяльності, що призводить до забруднення водойм та погіршення якості води. У роботі здійснена екологічна оцінка якості води озер Волинської області, які найбільш інтенсивно використовуються в рекреації. Вибір саме цих озер зумовлений розвитком рекреаційної інфраструктури, щорічним зростанням кількості рекреантів, великими розмірами озер, значною рекреаційною ємністю і потенціалом, розміщенням водойм у різних озерних групах. Екологічна оцінка якості озерної води здійснювалась відповідно до Методики оцінки якості поверхневих вод за відповідними категоріями. Аналіз якісних показників озер Світязь, Велике Згоранське і Сомин засвідчив високу якість води. За період 2015–2019 рр. на всіх озерах якість води відносилась до II класу «добрі», за ступенем чистоти «чисті», за категоріями – до II категорії «дуже добрі», за ступенем чистоти «чисті». Для оз. Велике Згоранське за ці роки величина I_E змінювалась в інтервалі 1,81–2,44, для озера Світязь – 1,66–2,07, для озера Сомин – 2,56–2,96. На величину екологічного індексу якості води найбільший вплив має індекс I_2 (еколого-санітарні показники). Встановлено перевищення гранично-допустимих концентрацій за окремими компонентами. Не дивлячись на ці перевищення, в цілому, якість води дозволяє використання озер в різних галузях господарства. Комплексна оцінка якості озерних вод необхідна для визначення головних напрямів водоохоронної діяльності, поліпшення екологічного стану озер та їхніх водозборів. Це дозволить більш раціонально використовувати озера, перш за все у рекреації, забезпечить ефективний моніторинг озер з метою своєчасного інформування відпочивальників про якість води та пов'язаних з нею потенційних небезпек для їх здоров'я.*

Ключові слова: *озеро, якість води, гранично-допустима концентрація, блокові індекси якості води, інтегральний екологічний індекс якості води, екологічна оцінка якості води, класи якості води, категорії якості води.*

В. А. Фесюк, Л. В. Ильин, И. А. Мороз, О. В. Ильина. ЭКОЛОГИЧЕСКАЯ ОЦЕНКА КАЧЕСТВА ВОДЫ РАЗНОТИПНЫХ ОЗЕР ВОЛЫНСКОЙ ОБЛАСТИ, КОТОРЫЕ ИНТЕНСИВНО ИСПОЛЬЗУЮТСЯ В РЕКРЕАЦИИ. *Озера Волынской области имеют важное природное и хозяйственное значение. Побережье озер интенсивно используют в рекреационной деятельности, что приводит к загрязнению водоемов и ухудшению качества воды. В работе осуществлена экологическая оценка качества воды озер Волынской области, которые наиболее интенсивно используются в рекреации. Выбор именно этих озер обусловлен развитием рекреационной инфраструктуры, ежегодным ростом количества рекреантов, большими размерами озер, значительной рекреационной емкостью и потенциалом, размещением водоемов в различных озерных группах. Экологическая оценка качества озерной воды осуществлялась в соответствии с Методикой оценки качества поверхностных вод по соответствующим категориям. Анализ качественных показателей озер Свитязь, Большое Згоранское и Сомын показал высокое качество воды. За период 2015–2019 гг. качество воды всех озер относилось к II классу «добрые», по степени чистоты «чистые», по категориям – к II категории «очень хорошие», по степени чистоты «чистые». Для оз. Большое Згоранское за эти годы величина I_E менялась в интервале 1,81–2,44, для озера Свитязь – 1,66–2,07, для озера Сомын – 2,56–2,96. На величину экологического индекса качества воды наибольшее влияние имеет индекс I_2 (эколого-санитарные показатели). Установлено превышение предельно-допустимых концентраций по отдельным компонентам. Несмотря на эти превышения, в целом, качество воды позволяет использование озер в различных отраслях хозяйства. Комплексная оценка качества озерных вод необходима для определения основных направлений водоохранной деятельности, улучшения экологического состояния озер и их водосборов. Это позволит более рационально использовать озёра, прежде всего в рекреации, обеспечит эффективный мониторинг озёр с целью своевременного информирования отдыхающих о качестве воды и связанных с ней потенциальных опасностей для их здоровья.*

Ключевые слова*: озеро, качество воды, предельно-допустимая концентрация, блочные индексы качества воды, интегральный экологический индекс качества воды, экологическая оценка качества воды, классы качества воды, категории качества воды.*

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Introduction. There is a close link between the health status of the population and the environmental factors that affect it. One such factor is surface water bodies, used to meet economic, domestic and other human needs. Human health largely depends on the water status of the lakes used for recreational activities. New types of contaminants, that have not previously existed, emerge and are continuing to emerge: radioactive, toxic, biological, etc. They can cause significant damage to not only lake ecosystems, but also to human health. Considering the above, assessing the ecological status of lakes and their protection against pollution is essential for the conservation and promotion of recreants' health.

The urgency of the lakes study is due to their significant share in the spatial structure of landscapes, enhanced anthropogenic and natural transformation of natural reservoirs of local and regional levels, poor understanding of the laws of the functioning of reservoirs and the need for gaining understanding to solve problems of scientific and economic importance. Development of protection measures and rehabilitation of the aquatic environment takes an important place in rational use of resources, while taking into account economic activities in the catchment area and within the reservoirs. The detailed study and forecast of variants of anthropogenic loads on lakes serves as a basis for the development of water conservation measures. Modern understanding of the rationalization problem of nature management and nature conservation, the need to introduce intensive forms of resource use in combination with resource-saving technology, all lead to considerable attention to the assessment of the quality status of lakes.

P**urpose of the article.** The purpose of the article is ecological assessment of water quality in various lakes of Volyn Region, which are most intensively used in recreation.

Analysis of recent research and publications. A considerable amount of work is devoted to the problem of lake water quality assessment. It is carried out in three directions, combining the following indicators: factors related to the physical, geographical and hydrological characteristics of the reservoir as a whole object [10, 15, 21, 25–26]; controlled indicators of the composition and properties of the aquatic environment, which provide an assessment of water quality and its compliance with current standards [1–3, 6–7, 11–14, 19–20, 23–24, 29–30]; set of criteria that determine the specifics of structural and functional organization and dynamics of the limnosystem [8–9, 22]. The suitability of reservoirs for certain types of recreational use for a certain set of indicators (radiological, hydrochemical, climatic, sanitary and hygienic, etc.) is considered in the works [5, 27, 31–33]. Methodological aspects of surface water quality assessment are proposed in [4, 14, 16–18, 28]. However, the issue of lake water quality assessment requires detailed research and is an important prerequisite for assessing the recreational potential of water bodies.

Materials and methods. The materials of expeditionary studies on the assessment of the natural and economic status of lakes, as well as the results of the chemical analysis of water by the Laboratory for Monitoring of Waters and Soils of the Regional Office of Water Resources in Volyn Region and the Complex Laboratory for Observation of the Environmental Pollution Center hydrometeorology (CGM) were used during the research. Research methods are expeditionary (for lake status assessment), methods of mathematical statistics (to statistically process the results of monitoring) and environmental assessment of water quality. Ecological assessment of lake water quality was carried out in accordance with the Methodology of surface water quality assessment in the respective categories. The system of ecological classifications forms the basis for the assessment of lake waters based on three blocks of indicators: salt composition of water; trophic-saprobiological (ecological-sanitary) indicators of water; specific water substances of toxic effect [18].

The block of indicators of water salt composition (block index I_1) includes specialized classifications of water quality according to the following criteria: mineralization, ionic composition (hydrochemical type of water), contamination with components of salt composition of water (chlorides, sulfates, mineralization) [18].

Tropho-saprobiological (ecological-sanitary) block (block index I_2) includes the following groups of indicators: hydrophysical, hydrochemical (suspended substances, pH, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phosphates, dissolved oxygen, biochemical consumption of oxegen) hydrobiological, bacteriological, etc.

The block of specific substances of toxic action (block index I_3) includes specialized classifications of water quality according to the content of specific substances of water (copper, iron, manganese, nickel, chromium) and toxicity level [18].

In general, the environmental assessment lies in determining the block water quality indexes for each of the three blocks (I_1, I_2, I_3). An integrated environmental index of I_E (average of the sum of $I_1 + I_2 + I_3$) was calculated for a comprehensive assessment of water quality [18].

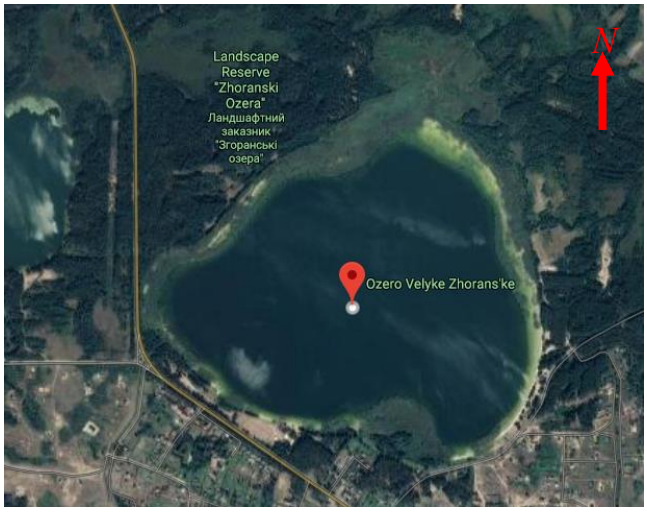
Results. The lakes and their coast lines are the main objects of recreational activity in Volyn Region. Resort and recreational development of reservoirs is a special type of water use. Although the amount of water used in this industry for drinking

and medical purposes in sanatoriums, holiday homes, boarding houses, camp sites is relatively small, the development of a spa and recreational facilities requires significant additional volumes of fresh water to maintain the depth of water in the bathing area, certain sanitary facilities and temperature regimes of reservoirs. The limiting factors are the sanitary and hygienic indicators of water. First of all, high quality of water should be provided for the organization of contact types of recreation (bathing, scuba diving, water skiing, etc.).

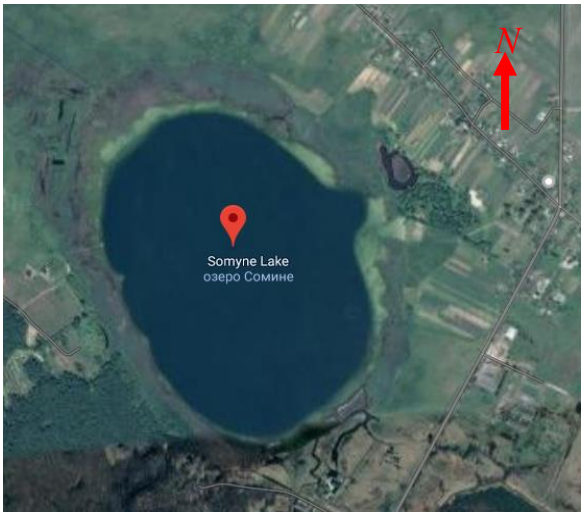
In our opinion, there are three most recreationally developed lakes of Volyn Region: Svitiaz, Somyn and Velyke Zgoranske (Fig. 1). The choice of these lakes may be explained by the following factors: development of recreational infrastructure and a significant annual increase in the number of recreation; large sizes of lakes; significant recreational capacity and potential; placement of reservoirs in different lake groups (Lake Svitiaz – Shatsk lakes, Lake Velyke Zgoranske – Zgoransk group of lakes, Lake Somyn – Turiysk group of lakes).

Lake Svitiaz (51.4966478 N, 23.8461256 E) – the deepest lake and one of the largest lakes in Ukraine; it is part of the Shatsk National Nature Park. It is inferior in area to only a few Danube lakes. The lake area is 2750.2 ha, maximum length is 9283 m, width is 4822 m. The coastline is undivided. The bottom of the lake can be divided into two hollows – west and east, which are separated by rising above the water surface – the island. There are the largest cavities and the greatest depth of the lake (58.4 m) in the western part of the lake. In the eastern part, the entire bottom area, starting from the southern shores, is a gentle slope to the center of the lake with a marked decrease in depths to the east and west.

According to the nature of the thermal regime,



a. Scale: 1:14285



b. Scale: 1:13642

c. Scale: 1:43290

Fig. 1. Lake shots from space (based on map service Google Maps):

a. Lake Velyke Zgoranske
b. Lake Somyn
c. Lake Svitiaz

Lake Svitiaz refers to the lake type of moderate latitudes with pronounced direct stratification in the summer, reverse – in winter and homothermia in spring and late autumn. Maximum surface water temperature occurs in July-August and reaches 24.5 °C, in the central part of the lake the temperature is slightly lower (19–20 °).

The lake water level is characterized by spring and autumn rise. In the spring, the rise of the level is associated with the melting of snow, at the end of

May the level reaches its maximum, afterwards – the level decreases and its fall lasts until October. Starting in October, there is a rise, which is influenced by autumn rainy floods. This rise peaks early in the winter, and then gradually decreases to a preemptive minimum. The height of the rise on average is 0.3–1.0 m. The decline of its levels occurs gradually, as high levels are maintained by the June-July rains. The reservoir is fed by atmospheric precipitation and groundwater. In addition to atmospheric precipitation, the lake's waters are accompanied by groundwater, with a water-resistant chalky surface layer, as well as the waters of the Cretaceous and underlying horizons below, which contributes to the considerable depth of the lake.

In the summer of 2019, the water level of Lake Svitiaz has been anomalously decreased by 0.38 m (the water receded from the shores by 60–90 m). This has raised national concern about the status of the lake ecosystem of this unique site. In our opinion, this is due to the abnormally low rainfall and hot summers, as well as the intensification of the use of groundwater in the catchment area as a result of the massive construction of wells at a depth of 30–50 m (Fig. 2).

The content of water-soluble oxygen in the summer is up to 13.2 mg/dm^3. Oxygen deficiency is not observed in the bottom layers. The amount of organic matter and biogenic elements is negligible in the lake water. Oxidation ranges from 7.8 to

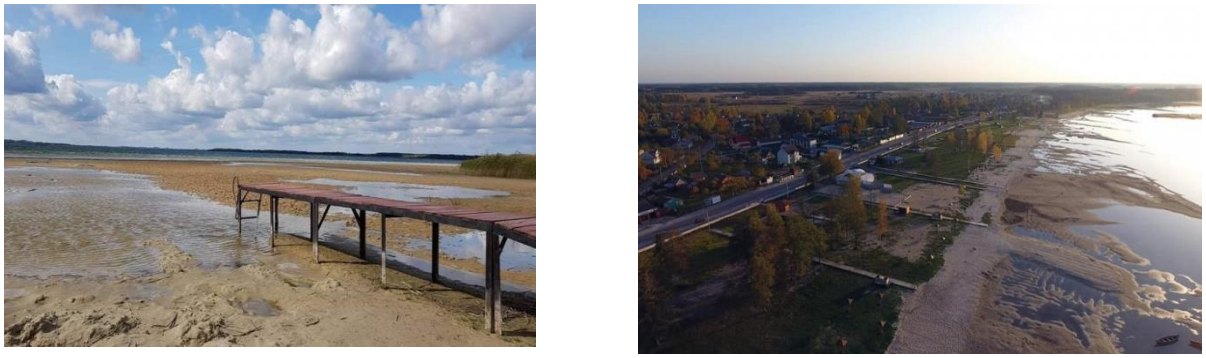


Fig. 2. Abnormal decrease in water level of lake Svitiaz (Summer 2019)

12 mg O_2/dm^3 in different areas in July-August.

Lake Somyn (51.1964602 N, 24.3234086 E) is located in the east of village Somyn of Turiysk district. Water body is of karst origin. The lake area is 123.8 ha and the catchment area is 39.5 km^2. The maximum depth is 56.9 m, the average depth is 12.77 m. The maximum length is 1.28 km. The maximum width is 1 km. The volume of the lake is 13100000 m^3. Its water is very clean, transparent and its quality may compete with the water of Lake Svityaz.

There are numerous recreation areas of various degrees of equipment on the southern shore. The lake has been very heavily used in recreational activities lately. The number of recreational facilities and vacationers is increasing every year. This is facilitated by a shorter distance from Lutsk than for Lake Svityaz and such factors as good transport accessibility, clean water and attractiveness of the reservoir.

Lake Velyke Zgoranske (51.3727783 N, 23.9797211 E) – the largest lake based on the area of all Zgoransk lakes and it is located in the north of village Zgoriyany Luboml district. Length is 1.5 km, average width – 1 km, area – 148.5 ha, average depth – 10 m, maximum – 20 m, basin is of oval shape, height of the water cut in the lake – 168 m. The shores are located on lowland, are sandy and sometimes swampy. It is fed by groundwater and precipitation. The lake bottom is sandy, covered with a layer of sapropel (reserves are 1511.2 tons). The shores are swampy, sometimes overgrown with mixed forest (mainly north and west shores). There are numerous recreational areas of various levels of equipment on the southern shore.

When assessing the ecological status of lakes, comprehensive indicator is usually sought that takes combined effect of a variety of factors into account. Developing such an indicator causes many complications even for an individual reservoir. However, the use of a comprehensive indicator of its environmental status is very important and requires careful study in order to determine the efficiency of regional lake resources usage. On the basis of comparison, the categories and classes of water quality were determined according to separate indicators that were taken for a single assessment. The results are presented as a single environmental assessment, which is based on the final conclusions of the three blocks.

An indispensable condition for performing ecological assessment of surface water quality utilizing both ways is strict adherence to generally accepted methods of the composition analysis and the properties of water in selected samples by many indicators or techniques developed by authoritative experts in their fields of expertise and their long-term testing [18].

Environmental assessment of water quality of Lake Velyke Zgoranske for the years of 2015–2019, which was carried out as a result of observations of the state and chemical analysis of the water composition and conducted by the Laboratory for Monitoring Waters and Soils of the Regional Office of Water

Table 1

Classes and categories of surface water quality by ecological classification [18]

Water Quality Classes	I	II		III		IV	V
Water Quality Categories	1	2	3	4	5	6	7
Name of water quality classes and categories according to their natural state	Excellent	Good		Satisfactory		Bad	Very Bad
	Excellent	Very Good	Good	Good Enough	Mediocre	Bad	Very Bad
Name of classes and categories of water quality according to its degree of cleanliness (pollution)	Very Clean	Clean		Polluted		Dirty	Very Dirty
	Very Clean	Clean	Clean Enough	Slightly Polluted	Moderately Polluted	Dirty	Very Dirty
Tropholytic	Oligotrophic	Mesotrophic		Eutrophic		Polytrophic	Hypertrophic
	Oligotrophic-oligomesotrophic	Mesotrophic	Mesoeutrophic	Eutrophic	Euplytrophic	Polytrophic	Hypertrophic
Saprobility	Oligosaprobic		β-mesosaprobic		α-mesosaprobic		Polysaprobic
	ß-oligosaprobic	α' - oligosaprobic	β'-mesosaprobic	β''-mesosaprobic	α'-mesosaprobic	α''-mesosaprobic	Polysaprobic

Resources in Volyn Region for the years of 2015–19 according to the materials of the Water and Soil Monitoring Laboratory of the Regional Water Resources Office in Volyn Region and the Integrated Laboratory for Observation of Natural Pollution of Volyn CGM, Lake Somyn for the years of 2015–18 according to the materials of the Water and Soil Monitoring Laboratory of the Regional Water Resources Office in Volyn Region. The assessment was carried out according to the full program with an indicative purpose – to assess the current natural and economic status of the lake, based on ecological assessment of the lake water quality, to identify the main problems and to suggest ways of their solution.

According to the results of the analysis of the chemical composition of water in Lake Velyke Zgoranske in 2019, the concentration of ammonium saline was exceeded above the limited concentration of substance by 60%, and the total iron content was doubled (Fig. 3). The same exceedances occurred for ammonium saline in 2018 (by 68%), in 2017 (by 56%), in 2016 (by 2.4 times), in 2015 (4%). In 2018, total iron amount – was exceeded by twice, in 2017 – 2.3 times, in 2016 – 1.9 times; chemical oxygen consumption in 2018 – 2.85 times; manganese in 2018 – 1.5 times, in 2017 – 10 times, in 2016 – 4 times, in 2015 – 12 times, copper in 2015 – twice.

Limited concentration of substance was exceeded by iron content (by 20%), copper (by 2.9

times), chromium (VI) (by 80%) in the waters of Lake Svitiaz in July 12, 2019. On the other hand, excess was not identified in the content of organic substances as well as nitrogen (ammonium, nitrite and nitrate). Therefore, despite the problem of the Svitiaz shallowing, the content of pollutants in the lake water was exceeded by only a few indicators during the summer of 2019.

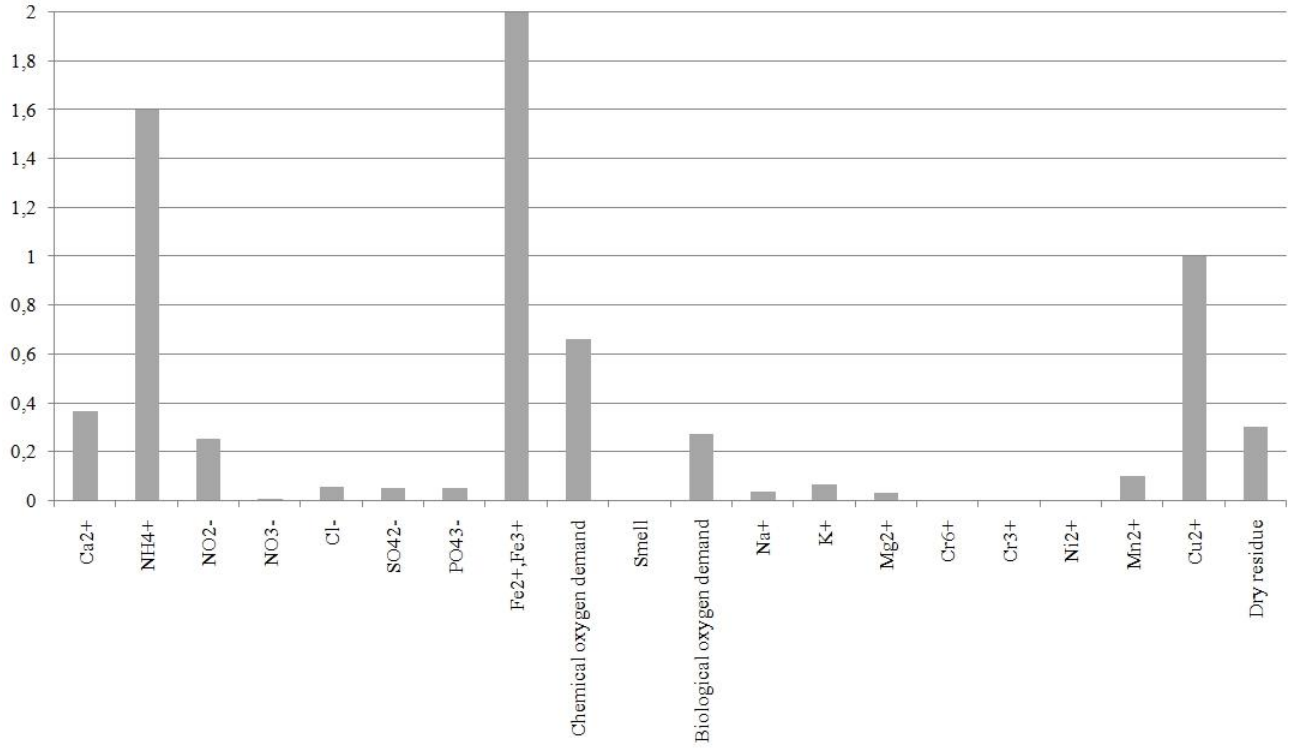


Fig. 3. Multiplicity of exceedance of the maximum permissible concentrations of pollutants in the water of the Lake Velyke Zgoranske (August 1, 2019) (summarized from materials from the Water and Soil Monitoring Laboratory of the Regional Water Resources Office in Volyn Region)

Results of ecological assessment of lake water quality of Velyke Zgoranske are provided in table 2. The water of the lake belongs to water quality class – „good", in terms of purity – „pure". In terms of quality category – „very good", „clean" for the period of observations (2015–2019) by the magnitude of the ecological index. However, there were some differences in the subcategories in some years: for example, lake water quality had a tendency of approaching the „excellent", „very clean" categories in 2019, 2017, 2016, and referred to categories „good", „clean enough" in 2015 and 2018. Fig. 4 shows that these years are characterized by the highest values of the Ecological Water Quality Index *(I_E)*.

Therefore, the most significant value of the ecological water quality index (I_E) in Lake Velyke Zgoranske is affected by the indexes of I_2 (trophic-saprobiological or ecological-sanitary indicators). They vary in the interval from 2.6 to 4. The block index, which takes into account the specific indica-

Table 2

Lake water quality assessment. Velyke Zgoranske (2015–2019 yrs.)

Year	Sampling date	Value I_E	Evaluation					
			Category	Class	State by Class	Degree of class purity	Condition by category	The degree of purity by category
2019	01.08	1,81	2	2	Good	Clean	Very good	Clean
2018	30.05	2,44	2	2	Good	Clean	Very good	Clean
2017	09.08	2,1	2	2	Good	Clean	Very good	Clean
2016	15.08	2,06	2	2	Good	Clean	Very good	Clean
2015	17.08	2,34	2	2	Good	Clean	Very good	Clean

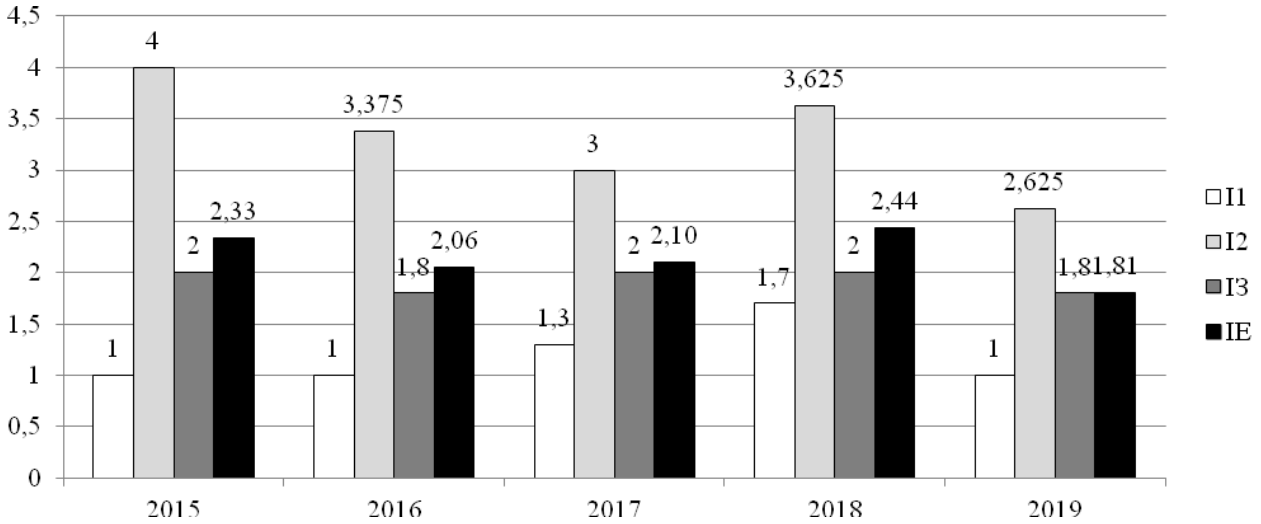


Fig. 4. Dynamics of ecological index of water quality *(I_E)* and its components in the Lake Velyke Zgoranske

tors of toxic and radiation action (I_3), does not change by year and corresponds to 1. In some years, there was deterioration of the block index of salt composition (I_1). Thus lake waters were assigned to the second category of quality, in particular, in 2018 by chloride and sulphate content and in 2017 – by sulphate content (Table 2).

For the period of our research (2015–2019), Svitiaz belongs to the class of water quality – „good", in terms of purity – „pure" by the magnitude of the ecological water index of lake. In terms of quality category – „very good", „clean". But in the sub-categories, there were some differences in some years. For example, for all years except 2017, the waters are in transition from „excellent, very clean" to „very good, clean". In 2017, sub-category of water quality was rated as „very good, clean". Results of ecological assessment of water quality of Lake Svitiaz are shown in table 3.

A similar trend is observed in the structure of the ecological water quality index, as for the Lake Velyke Zgoranske. The most significant value of the ecological water quality index (I_E) in Lake Svitiaz is influenced by the indexes I_2 (trophic-saprobiological or ecological-sanitary indices). They vary in different years in the range from 1.625 to 2.875, which is much lower than for Lake Velyke Zgoranske. The block index, which takes into account the specific indicators of toxic and radiation action (I_3), changes much less over the years – from 1.6 to 2.2. The deterioration of the block index of salt composition (I_1) was also observed in some years (Fig. 5). Thus, lake waters were classified as second quality category in 2018 by chloride content (20.8 mg/dm^3).

Results of ecological assessment of water quality of Lake Somyn are given in table 4. Based on the table, it can be seen that in all the years the water quality of the lake is evaluated by the class "good", the degree of purity by the class - "pure". The Ecological Water Quality Index ranged from 2.56 to 2.96. In the category of quality – „good", the purity category – „fairly pure". There were some differences in the subcategories in some years: for example, in 2017, 2016, lake waters were rated as transient in quality from „very good", „clean" to „good", „fairly pure". And in 2015 and 2018 – the categories of „good", „fairly clean" gravitate to the category of „very good", „clean". Based on Figure 6, it can be seen that these years are characterized by the highest values of the Ecological Water Quality Index *(I_E)*.

There is no longer a rigid dependence of the

Table 3

Water quality assessment of Lake Svitiaz (2015–2019 yrs)

Year	Sampling Date	Value I_E	Evaluation					
			Categoty	Class	State by Class	Degree of class purity	Condition by Category	The degree of purity by category
2019	12.07	1,54	2	2	Good	Clean	Very good	Clean
2018	30.05	1,79	2	2	Good	Clean	Very good	Clean
2017	09.08	2,07	2	2	Good	Clean	Very good	Clean
2016	15.08	1,99	2	2	Good	Clean	Very good	Clean
2015	10.06	1,66	2	2	Good	Clean	Very good	Clean

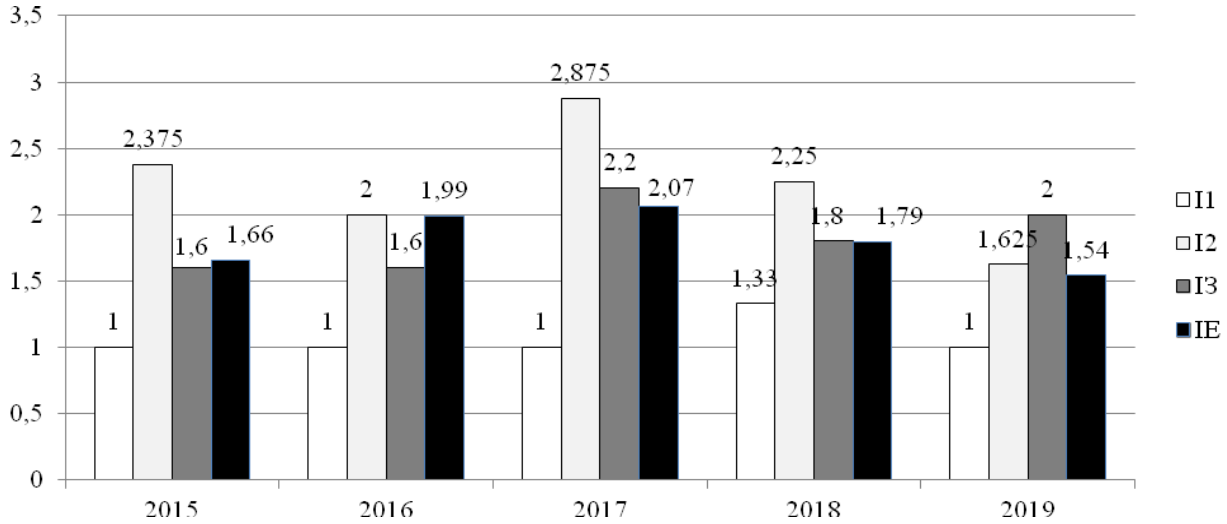


Fig. 5. Dynamics of ecological index of water quality *(I_E)* and its components in Lake Svitiaz

Table 4

Water quality assessment of Lake Somyn (2015–2019 yrs)

Year	Sampling Date	Value I_E	Evaluation					
			Category	Class	State of Class	Degree of class purity	Condition by Category	The degree of purity by category
2018	26.06	2,83	2	3	Good	Clean	Good	Clean enough
2017	09.08	2,56	2	3	Good	Clean	Good	Clean enough
2016	24.05	2,71	2	3	Good	Clean	Good	Clean enough
2015	26.05	2,96	2	3	Good	Clean	Good	Clean enough

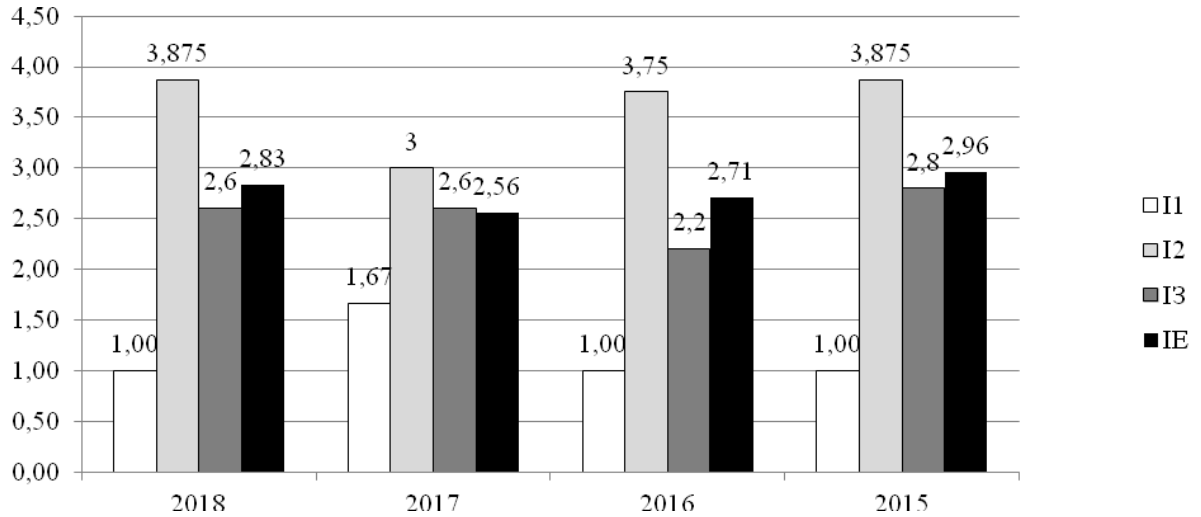


Fig. 6. Dynamics of ecological index of water quality (I_E) and its components in Lake Somyn

environmental index of water quality I_E on I_2 (trophic-saprobiological or ecological-sanitary indicators) for Lake Velyke Zgoranske, Lake Svitiaz, and Lake Somyn. However, I_2 is still quite influential. The numerical values of this index vary from 3 to 3.87 in different years. The block index, which takes into account the specific indicators of toxic and radiation action (I_3), varies annually in the range of 2.2–2.8. I_E is the least affected by the block index of salt composition. In some years, its deterioration is also noted. Thus, lake waters were classified as second quality category in 2017 by chloride content (34.7 mg/dm^3).

An important component of our study is the comparison of the results of environmental assessment of water quality of various lakes, which are intensively used in recreation (Table 5, Fig. 7). In 2018, water quality was classified as „good” and

Table 5

Comparison of results of ecological assessment of water quality of the studied lakes (2018)

Year	Sampling date	Value	Evaluation					
		I_E	Category	Class	State of Class	Degree of class purity	Condition by Category	The degree of purity by category
Lake Velyke Zgoranske								
2018	30.05	2,44	2	2	Good	Clean	Very Good	Clean
Lake Svitiaz								
2018	30.05	1,79	2	2	Good	Clean	Very Good	Clean
Lake Somyn								
2018	25.06	2,49	2	2	Good	Clean	Very Good	Clean

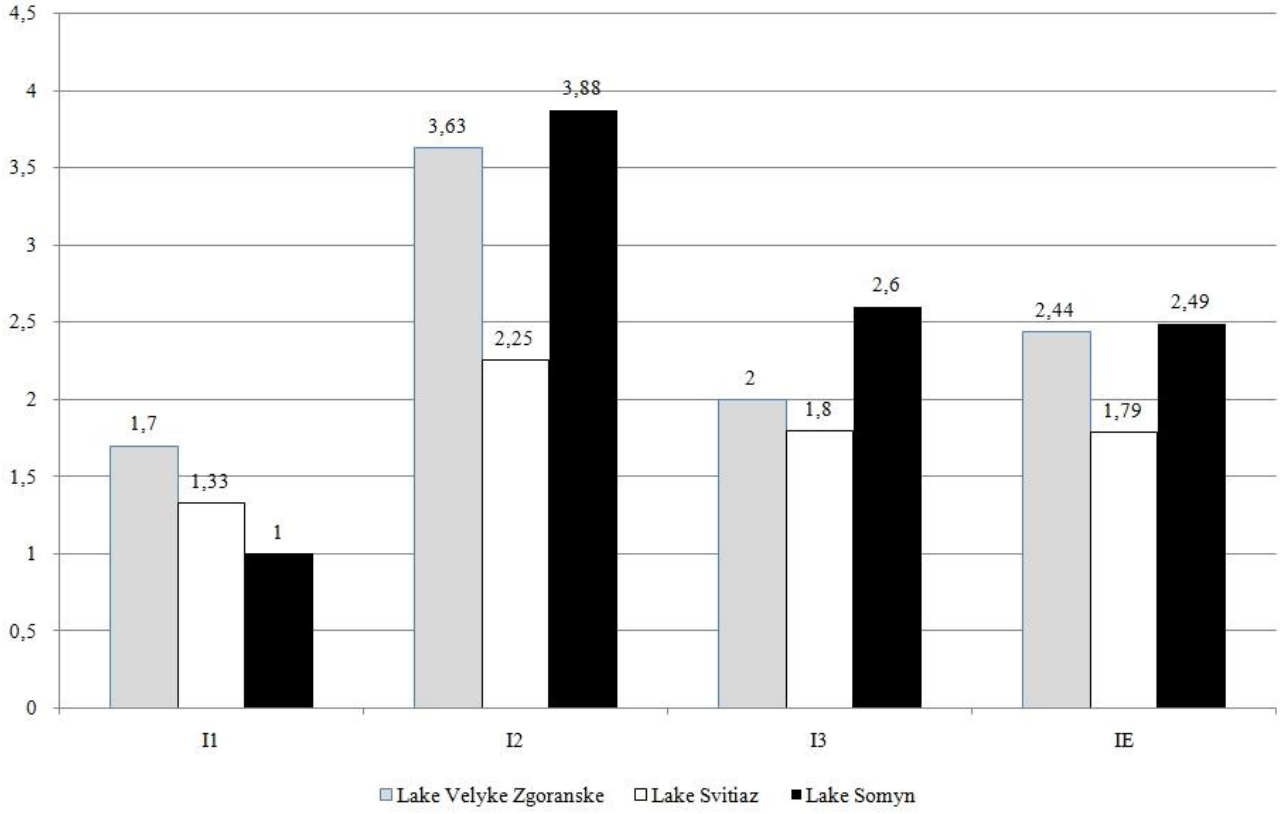


Fig. 7. Water quality indices of the studied lakes (2018)

referred to class II, cleanliness degree as „clean", by category – category II that are „very good" and „clean" according cleanliness level.

The Environmental Water Quality Index (I_E) was the lowest for the Lake Svitiaz (1.79). Indexes were slightly higher – 2.44 and 2.49 for lakes Velyke Zgoranske and Somyn, respectively. The results of the analysis show that Lake Svitiaz is one of the purest recreational natural reservoirs of Volyn. In the context of sub-categories I_E of lake Svitiaz belongs to the category „very good", „clean" with inclination to the categories „excellent", „very clean" according to water quality while the index is similar for the other studied lakes and their water quality corresponds to „very good", „clean" with a tendency to approach the category of „good", „fairly clean".

According to the indicators of partial indexes, fluctuations in environmental assessment occurred. The most significant value of the ecological index of water quality (I_E) in the lakes is affected by the indexes I_2 (trophic-saprobiological or ecological-sanitary indicators). The value of this block index did not go beyond the boundaries of the category II for Lake Svitiaz (I_2 = 2.25) and refers to „very good", „clean" water, while this characteristic refers to quality class III for the Lake Velyke Zgoranske (3.63) and Lake Somyn (3.88) and refers to „satis-

factory", „contaminated" and category IV – „good enough", „slightly contaminated".

According to the criterion of salt composition, the environmental assessment has several other features: the smallest index I_1 that is found in Lake Somyn (1), in Svitiaz (1.33), and in Lake Velyke Zgoranske where the index value was maximum – 1.77. The content of toxic substances (I_3) for the lake Velyke Zgoranske is similar to Lake Svitiaz. The value of this index for the waters of these lakes are compared: 2 and 1.8, and this is the second category – „very good", „clean" water. Instead, the value of I_3 is 2.6 in the waters of the Somyn Lake, which indicates that it belongs to the third category – „good", „fairly clean" water.

It is noteworthy that a comparative environmental assessment of the water quality of the studied lakes in 2019 has been constantly mentioned in the media about catastrophic shallowing of Lake Svitiaz. The question is: how did lake water level lowering affect water quality? It should be noted that the lakes Somyn and the Velyke Zgoranske did not suffer a significant decrease in water level in hot and dry summer of 2019, however, this is a very significant problem for Lake Svitiaz. This necessitated a comparative assessment of the water quality of the studied reservoirs for 2019 (Table 6).

According to the results of the study, the water quality in 2019 of Svitiaz and Velyke Zgoranske lakes belongs to the second class – „good", by the degree of purity – „pure", by categories – to the II category „very good", by the degree of purity „pure" (Table 6, Fig. 8).

Table 6

Comparison of the results of the ecological assessment of water quality in the Lake Velyke Zgoranske and Lake Svitiaz (2019)

Year	Sampling date	Value I_E	Evaluation					
			Category	Class	State of Class	Degree of class purity	Condition by Category	The degree of purity by category
Lake Velyke Zgoranske								
2019	01.08	1,81	2	2	Good	Clean	Very Good	Clean
Lake Svitiaz								
2019	12.07	1,54	2	2	Good	Clean	Very Good	Clean

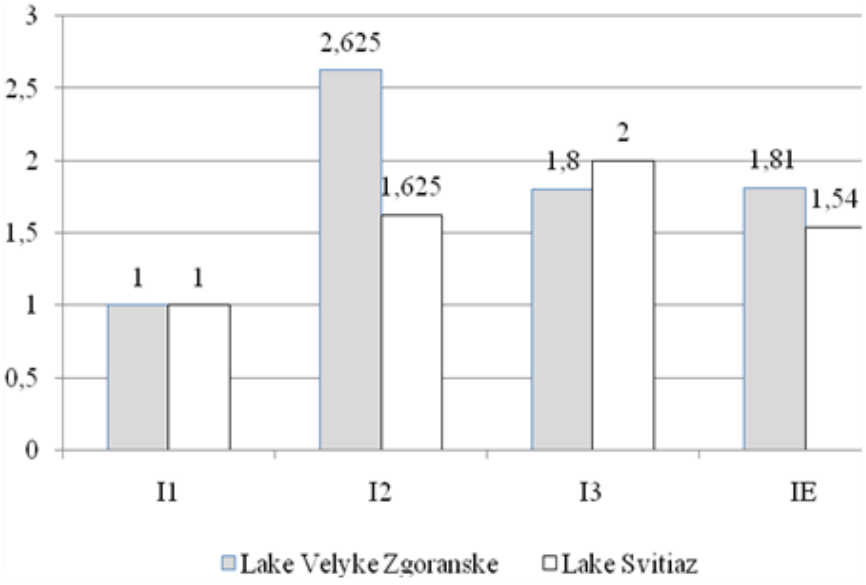


Fig. 8. Comparison of results of ecological assessment of water quality in the lakes of Velyke Zgoranske and Svitiaz (2019)

The Environmental Water Quality Index (I_E) was lower for the Lake Svitiaz (1.54). This index has been slightly higher for Lake Velyke Zgoranske – 1.81, despite the considerable shallowing of the lake. In the sub-categories of I_E for Lake Svitiaz, the water quality is defined as transitional from the category „excellent", „very pure" to „very good", „pure" while at that time for the Lake Velyke Zgoranske sub-category is defined as „very good", „clean" with an approximation to the category „excellent", „very clean".

According to the values of partial indexes, chan-

ges in the ecological status of water occurred. According to the criterion of salt composition, lake water has the same high score (1.0), which corresponds to the first class. Index I_2 (trophic-saprobiological or ecological-sanitary indicators) is significantly higher for Lakes Velyke Zgoranske (2.6). This testifies belonging to the third category – the waters are transient in quality from „very good", „pure" to „good", „quite pure". The value of this block index is estimated as water for Svitiaz (I_2= 1.625), which transitions in quality from „excellent", „very pure" to „very good", „pure". According to the criterion of the content of substances of toxic effect (I_3), the water of Lake Velyke Zgoranske (1.8) is of better quality than in the Lake Svitiaz (2.0). Both reservoirs are categorized as „very good", „clean" waters.

Conclusions. The ecological assessment of the water quality of the lakes showed that for the period 2015–2019, the water quality was classified as „good" class II, by degree of purity „clean", by categories – refers to category II „very good", by degree of purity „clean" for all lakes. During these years, I_E varied in the range of 1.81–2.44 for the Lake Velyke Zgoranske, in the range of 1.66–2.07 for the lake Svitiaz, and in the range of 2.56–2.96 for the Lake Somyn.

The water quality of the studied lakes is very high even given the impact of global climate change and the shallowing of some of the lakes. This allows the use of lakes for a variety of economic needs. Among these, of course, the most preferred type is recreational use. At the same time, the development of recreation, and especially the natural one, can worsen the ecological status of the lake. Therefore, recreational use should be made subject to proper hydro-environmental monitoring. In addition, a set of conservation measures should be implemented to protect the investigated lake ecosystems from sewage, field and farm runoff, shoreline contamination, recreational digression, and the negative impact of drainage land reclamation.

The economic use of lakes is differentiated and depends on several determining factors: their location and accessibility, availability of necessary reserves and quality of coastal resources of reservoirs and coasts (water, fishery, mineral, recreational), development of coasts and catchments (availability near settlements).

An important area of optimization of lakes is their reclamation – restoration of lakes and development of scientifically grounded limnosystem management measures.

It should also be taken into account, that in addition to the general remediation paths, for each case, the development of specific measures is needed, that take into account local features of a small catchment area, genetic degree of its stability, capacity and composition of sediments, sources of eutrophication or pollution.

Promising areas for further research are the definition of criteria that will allow us to evaluate the quality of lake waters, taking into account optimization measures as well as a predictive assessment of changes in water levels due to changes in lake water due to climate change already occurring today.

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ENVIRONMENTAL ASSESSMENT OF WATER QUALITY IN VARIOUS LAKES OF THE VOLYN REGION, WHICH IS INTENSIVELY USED IN RECREATION

Introduction. Assessment of the ecological status of lakes is important for their conservation and protection. Many lakes are intensively used in recreation in Volyn Region. The development of the resort and recreational facilities requires significant additional volumes of fresh water to maintain the depth of the reservoirs in the bathing area, certain sanitary and temperature regimes of the reservoirs. The limiting factors are the sanitary and hygienic indicators of water. First and foremost, high quality of water should be provided for the organization of contact types of recreation (bathing, diving, water skiing, etc.).

The purpose of article. The purpose of the article is ecological assessment of water quality in various lakes of Volyn Region, which are most intensively used in recreation.

Methods. Research methods are expeditionary, methods of mathematical statistics and environmental assessment of water quality, which were carried out in accordance with the methodology for assessing the quality of surface water in the respective categories. During the preparation of the article, materials from their own expeditionary studies of the natural-economic state of the lakes were used, as well as the results of chemical analysis of the water composition conducted by the Water and Soil Monitoring Laboratory of the Regional Water Resources Office in Volyn Region and the Complex Laboratory for Observation of the Environmental Environmental Center.

Results. The analysis of the qualitative indicators of the lakes Svitiaz, Velyke Zgoranske and Somyn showed the high quality of water in the lakes. For the period of 2015–2019, water quality was classified as „good" class II, by degree of cleanliness „clean", by category as „very good", by degree of cleanliness „clean" on all lakes. The value of I_E for the Lake Velyke Zgoranske varied in the range of 1.81–2.44, in the range of 1.66–2.07 for the Lake Svitiaz, and in the range of 2.56–2.96 for the Lake Somyn. Index I_2 (ecological and sanitary indicators) has the most influence on the magnitude of the ecological index of water quality.

The scientific novelty lies in establishing block and integral indexes of ecological assessment of water quality, classes and categories of water quality of the most recreationally-developed lakes of Volyn Region, as well as in assessment of the dynamics of indicators of water quality of lakes during the years of 2015–19.

Practical significance is defined with the opportunity of development of a set of measures for the rational use and protection of lakes.

Keywords: lake, water quality, maximum permissible concentration, block water quality indexes, integrated ecological water quality index, environmental water quality assessment, water quality classes, water quality categories.

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