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ASSESSMENT OF THE STATUS OF THE SURFACE WATER OF THE BUZKY ESTUARY WITHIN MYKOLAIV CITY

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Abstract. An assessment of the surface water state resources was provided, which included the analysis of the components of the salt composition, namely chlorides and sulfates. The trophic-saprobiological (ecological-sanitary) index was determined taking into account the absolute values of indicators: suspended substances, pH, phosphates, dissolved oxygen, BOD_5. To determine the index of specific indicators of toxic action, the absolute values of the components were used: copper, zinc, oil products, etc. It was determined that the category of water quality according to the components of the salt composition in the pre-war period was 6.1, which is less than in 2022 (6.5); according to tropho-saprobiological indicators (environmental and sanitary) – the pre-war period is 4.3, which is less compared to 2022 (5.0); according to specific indicators – in the pre-war period it is less and is 4.7 compared to 2022, when this index was 5.0. All defined surface water quality classes correspond to the degree of pollution "dirty" or "very dirty" and the state "poor" or "very poor". During the studied period, there is a steady trend towards a gradual increase in hardness, dry residue, sulfates, and chlorides in surface water. The level of pH, BOD_5, dissolved oxygen fluctuates within the normal range with minor deviations.

Keywords: surface water quality, salt composition, tropho-saprobiological index, specific indicators of toxic action, water quality index.

1. Introduction

Water is not only a natural resource, but also an integral component of the existence of all living things on the planet. The part of water that is suitable for use by the population and industry is very limited and is only 3 % of the total volume of water resources. However, only 0.3 % of fresh water is concentrated in the most usable surface water bodies (lakes and rivers). Therefore, the problem of providing mankind with clean fresh water is urgent (Dynamika zaboru i vykorystannia vody po Mykolaivskii oblasti, 2016; Mitryasova et al., 2022a; Mitryasova et al., 2022b). Thus, the problem of water resources suitable for drinking was included in the list of main issues of the World Economic Forum in Davos as one of the biggest global risks in the future, and ensuring equal access to high-quality and safe drinking water for human health is a strategic task of the Water Strategy of Ukraine until 2050. (Khilchevskoho, 2006; Romashchenka, et al., 2015; Vodna stratehiia Ukrainy, 2022; Water Code of Ukraine, 1995; Water resources of Mykolaiv region, 2023).

Currently, the quality of surface water, which is a source of drinking water for 80 % of the population of Ukraine, is unsatisfactory and is characterized by a high content of anthropogenic pollutants, and groundwater, as a rule, is characterized by increased hardness, mineralization, as well as an above-standard content of organic substances, etc. (Mitryasova et al., 2022a).

According to the Ministry of Health, in 2021, the specific weight of the tested water samples that came from the sources of centralized water supply of the population did not meet the norms for sanitary and chemical indicators − 18.6 %, and for microbiological indicators − 19.6 % (Dynamika zaboru i vykorystannia vody po Mykolaivskii oblasti, 2016; Dynamika zaboru i vykorystannia vody po Mykolaivskii oblasti, 2021). The indicated problem is also aggravated by the use of

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morally outdated technological equipment in the process of water preparation.

Qualitative indicators of water composition are among the determining factors in assessing the state of water resources (Hrytsenko et al., 2012; Rehionalna dopovid, 2020; Rybalova, 2011; Vasenko et al., 2008). Assessment of the quality of surface water is the basis for the integrated management of water resources, and is also the basis for establishing environmental standards for water bodies (BUWR of Southern Buh, 2023; Voda pytna: vymohy ta metody kontroliuvannia yakosti, DSTU 7525:2014, 2014).The issues of comprehensive assessment of the quality of surface water resources have been addressed by many scientists. As the basis of the research methodology, the work of Hrytsenko A. V. et al. was taken into attention (Hrytsenko et al., 2012). The water problem is also relevant for the city of Mykolaiv, a "city on the wave", which as a result of military operations during the Russian-Ukrainian war on April 12, 2022, was left without a system of sustainable centralized water supply.

The object was to assess the state of surface water within the city of Mykolaiv under wartime conditions throughout 2022.

Following the goal, the task was set: to assess the state of the Buzky Estuary according to integrated hydrochemical indicators within the city of Mykolaiv under the conditions of martial law in 2022 and in the pre-war period in 2016–2021.

The object of the research is the water problem of the city during military operations and surface water within the city of Mykolaiv, namely the water of the Buzky Estuary.

The subject of the study is the assessment of the surface water state of the Buzky Estuary within the city of Mykolaiv based on integrated hydrochemical indicators.

2. Materials and Methods

The basic methodological basis of the research is the method of environmental assessment according to the relevant categories, which was developed by the Ukrainian Scientific Research Institute of Environmental Problems of the Ministry of Environmental Protection and Natural Resources of Ukraine based on the water legislation of Ukraine and the Water Code (Directive 2000/60/EC, 2003; Water Code of Ukraine, 1995).

Mathematical methods included data statistical processing, the method of average values in determining the level of surface water pollution, graphical representation of data for qualitative visual evaluation of results using the MS Excel software product.

The assessment of surface water quality within the city was performed based on sampling data, taking into account the ecological classification of surface water quality of Ukraine, which covers hydrophysical and hydrochemical indicators, respectively, "Methodology of ecological assessment of surface water quality by relevant categories" (Hrytsenko et al., 2012).

According to the methodology, water quality indicators were divided into three blocks:

- salt composition (IC);
- tropho-saprobiological (ecological and sanitary) (ITC);
- specific toxic effect (IT).

To determine the integral characteristic (I_E), calculations were carried out within each of the three blocks.

The ecological index of water quality (I_E) is calculated as the arithmetic mean of the pollution indices of the components of salt composition (Ic), tropho-saprobiological (I_{TC}) and specific indicators of toxic and radiation action (I_T). Gradations of the *EQI* index according to water quality classes are given in the EC guidance document "Common Implementation Strategy for the Water Framework Directive (2000/60/EC) [(Directive 2000/60/EC, 2003).

3. Results and Discussion

As of the second half of 2022 − the beginning of 2023, the city remained without a stable water supply system. Centralized water supply stopped on April 12, 2022, when Russian troops damaged the water pipeline that supplied water from the Kherson region. The Dnipro-Mykolaiv waterworks has a length of 73 km and was located in the temporarily occupied territory (Fig. 1).

After the destruction of the Dnipro-Mykolaiv water supply system, it was only possible to start water in the city on May 9, 2022, and only for technical needs. During 2022, the local authorities considered possible alternative sources of centralized water supply. Firstly, the drilling of wells in Mykolaiv, should organize the supply of drinking water to the apartments of Mykolaiv residents directly from underground water. However, near Mykolaiv there is not enough drinking water to provide it to all residents. In addition, geological studies are required for drilling wells. Still, it was decided to drill the wells in order to have some water that could also be pre-cleaned. Secondly, in order to provide the city with at least "technical" water, it was decided to draw water not only from wells, but also to use water from the Southern Buh for this.

Before getting into the city residents' taps, the water went through several stages of purification, namely: Taking water from the river → Primary chlorination and sedimentation → Secondary chlorination and pumping into the city areas.

All stages of cleaning, in essence, represent disinfection using the chlorination method. First, water is taken from the river and wells through special structures. After that, the water goes through the process of primary chlorination. Next, the water settles for a certain time in horizontal settling tanks and is directed to the final filtration. The final stage of cleaning is secondary chlorination. Then the water enters the reservoirs and then the pumping station pumps the water around Mykolaiv districts.

The average values of the water quality indicators that were supplied to the centralized water supply system of Mykolaiv city during 2022 are presented in the Table 1.

Fig. 1. Damaged water supply system "Dnipro-Mykolaiv" in the territory of the Kherson region, 2022

Table 1

The average values of water quality indicators of the centralized water supply system of Mykolaiv city compared to the standards of Ukraine and the EU

Indicator	Unit of measurement	Value	MPC, Ukraine	MPC, EU
1	2	3	4	5
pH		**8.1**	**6.5–8.5**	**6.5–8.5**
Taste, aftertaste	points	0	until 2	until 2
Smell, 20°C	points	1	until 2	until 2
Color	points	14	until 20	until 20
E.coli	CFU/dm^3	0	0	0
Microbial number	KOE/dm^3	12	until 100	
Phytoplankton	cells/dm^3	5000		
Dry residue	**mg/dm^3**	**10408**	**1000**	**1500**
The oxidizability is permanganate	mgO_2/dm^3	5.2	5.0	5.0
Hardness general	**mg-equivalent/dm^3**	**32**	**1.5–7**	**1.2**
Alkalinity	mg-equivalent/dm^3	4.1	0.5–6.5	
Chlorides	**mg/dm^3**	**4400**	**350**	**250**
Nitrates	**mg/dm^3**	**81.1**	**45**	**50**
Nitrite	mg/dm^3	0.015	3	0.5
Sulfates	**mg/dm^3**	**712**	**500**	**250**
Phosphates	mg/dm^3	0.43	3.5	0.7
Cyanides	mg/dm^3	0	0.035	0.05
Phenols	mg/dm^3	0	0.001	0
General iron	mg/dm^3	0.2	0.3	0.2
Ammonium nitrogen	mg/dm^3	0.1	2.0	0.5

Continuation of Table 1

1	2	3	4	5
Aluminum	mg/dm^3	0	0.5	0.2
Arsenic	mg/dm^3	0	0.05	0.01
Sodium	**mg/dm^3**	**4380**	**1000**	
Nickel	mg/dm^3	0	0.1	
Carbon organic	mg/dm^3	18.3		
Manganese	mg/dm^3	0	0.1	0.05
Molybdenum	mg/dm^3	0	0.25	
Cobalt	mg/dm^3	0	0.1	
Copper	mg/dm^3	0.065	1.0	2.0
Lead	mg/dm^3	0	0.03	0.01
Silicon	mg/dm^3	1.16	10.0	–
Chrome general	mg/dm^3	0	0.55	0.05
Zinc	mg/dm^3	0.048	5.0	5.0

In general, water in the city, which enters the centralized water supply system, does not correspond the requirements of drinking water quality according to several indicators. Thus, the indicator of dry residue, which had a value of 10408 mg/dm^3 (MPC − up to 1000 mg/dm^3), exceeded the norm by more than 10 times, which indicates a high level of water salinity. Chlorides had a value of 4400 mg/dm^3 with a norm of only 20 mg/dm^3, which can cause a person to have a disorder of the gastrointestinal tract. Sulfates had a value of 712 mg/ dm^3 with a norm of 250 mg/dm^3. The hardness of the water is 32 mg-eq/dm^3, the norm of which should be 1.5−7 mg-eq/dm^3, which can cause urolithiasis, because the water is very salty. Therefore, the hardness of the water exceeded the norm by five times. Indicators indicate that this water cannot be used as drinking water. Tastewise, the water is very salty and bitter.

The water also has the smell of chlorine, which is due to the intensive process of water disinfection. So, for example, the indicator of "common coliforms" was 0, which indicates that there are no coliforms in the water

So, as shown by the indicators in the Table 1, the water supplied to the centralized water supply system of the city of Mykolaiv could be used exclusively for technical domestic purposes, namely: sanitary hygiene of the residence, toilet, shower (partially), washing dishes (partially), keeping animals (partially), keeping flowers (partially). The use of such water for cooking is not permissible, and it is also not desirable for personal hygiene purposes.

Thus, the main sources of the city's drinking water supply under wartime conditions, when the main water supply “Dnipro-Mykolaiv” was destroyed, were: first, wells located on the territory of the private sector, some enterprises and institutions; secondly, imported water from other cities; third, bottled water. Typical water features of the city of Mykolaiv are shown in the photo, Fig. 2.

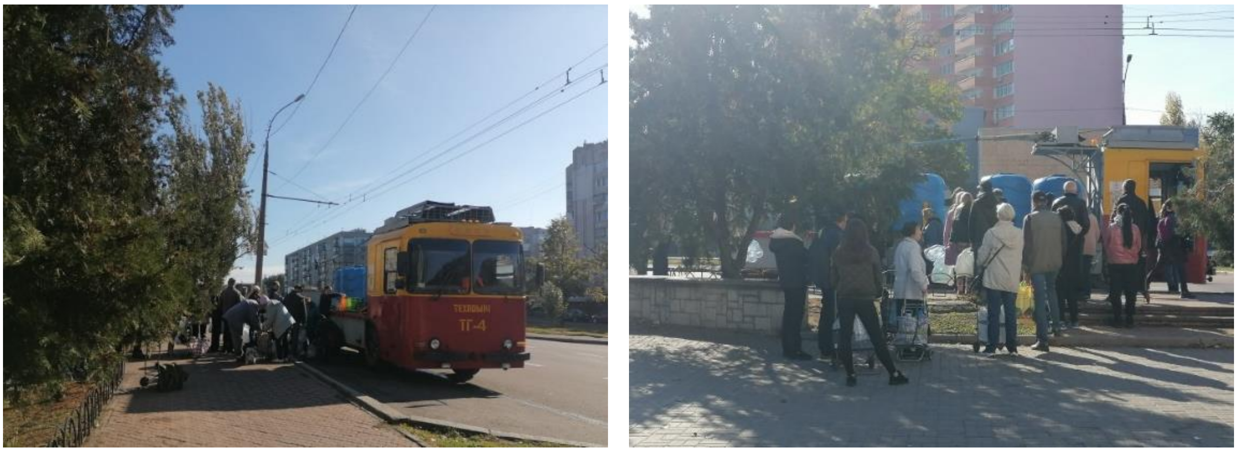

Fig. 2. The city's drinking water supply under wartime conditions

In order to assess the state of the surface water of the Buzky Estuary, the available hydrophysical and hydrochemical data were systematized.

The analysis was carried out according to the following indicators: pH; Suspended substances; Dissolved oxygen; BOD_5; Hardness general; Chlorides; Sulfates; Phosphates; Copper; Zinc; Petroleum products.

The definition of water quality categories based on indicators exceeding the MPC according to the environmental classification for each hydrochemical indicator made it possible to convert the absolute quantitative values of the indicators into unified integral indicators of water quality (indices, classes, categories).

Changes in the conditions of formation of water quality under the influence of anthropogenic factors are expressed by indices, and the limits of fluctuations of ecological indices are important for solving issues of water management, implementing environmental protection and restoration measures. Sampling points are shown in Fig. 3.

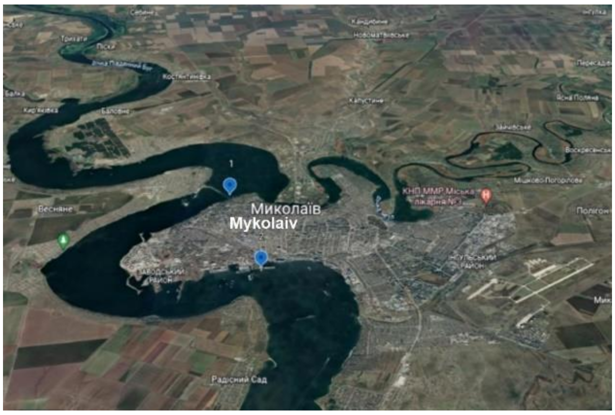

Fig. 3. A picture of Buzky Estuary within Mykolaiv city:
1 – Varvarivsky bride district (46.988920, 31.965766);
2 – Sea port (Cabotage Mall) (46.94488, 31.98788)

In order to define the categories and classes, the indicators that exceed the standards of the MPC were chosen. Mathematical calculations were carried out using the MS Excel software package.

The calculation of the ecological index of water quality (I_E) was carried out as the arithmetic mean of the indices of pollution by the components of the salt composition (I_c), tropho-saprobiological (I_{TC}), and specific indicators of toxic and radiation action (I_T).

Thus, the ecological index of the water quality of the Buzky estuary within Mykolaiv city in the pre-war period was:

$$I_E = \frac{I_C + I_{TC} + I_T}{3} = \frac{6,1 + 4,3 + 4,7}{3} = 5,03.$$

However, in 2022, the environmental index of the water quality of the Buzky Estuary within Mykolaiv city was:

$$I_E = \frac{I_C + I_{TC} + I_T}{3} = \frac{6,5 + 5,2 + 5,0}{3} = 5,57.$$

Ecological indices of the surface water quality of Buzky Estuary were calculated using the functions of the MS Excel software package and summarized in the Table 2.

Table 2

Ecological indices of the surface water quality of Buzky Estuary

Period	I_C	I_{TC}	I_T	I_E
2016	5.5	4.2	4.7	4.80
2017	6	4.4	4.7	5.03
2018	6	4.4	4.7	5.03
2019	6	4.2	4.7	4.97
2020	6	4.2	4.7	4.97
2021	6.5	4.4	4.7	5.20
2022	6.5	5.2	5.0	5.57

Formula 3 was used to convert the index of ecological assessment of water quality (I_E) to the range from 1 to 0. The index of ecological quality is given in the Table 3.

Table 3

The index of ecological assessment of water quality (EQI) to the range from 1 to 0

	2016	2017	2018	2019	2020	2021	2022
I_E	4.80	5.03	5.03	4.97	4.97	5.20	5.57
EQI	0.31	0.28	0.28	0.29	0.29	0.26	0.20
Water quality class	Poor	Poor	Poor	Poor	Poor	Poor	Bad

Note, that during the studied period there is a steady trend towards a gradual increase in the stiffness index. The level of pH, BOD_5, dissolved oxygen fluctuates within the normal range with minor deviations.

Analyzing the graphs of fig. 4, it is possible to highlight a steady trend towards a gradual increase in the content of dry residue, sulfates and chlorides in surface water. However, the concentration of chlorides and sulfates in surface water is subject to seasonal fluctuations and depends on the general mineralization of the water.

In river water and water of fresh lakes, the chloride content varies from fractions of a milligram to tens, hundreds, and sometimes thousands of milligrams per liter. In sea and underground water, the content of chlorides is much higher, and can reach supersaturated solutions and brines.

Since Buzky Estuary has access to the Black Sea, the chloride content depends on the amount of seawater inflow. The distribution and vital activity of organisms in the aquatic environment largely depend on its chemical composition. First of all, aquatic organisms are divided into freshwater and marine depending on the salinity of the water in which they live. An increase in the salinity of the water in the habitat leads to the loss of water by the body.

Such situation indicates that water resources in the studied territory have disturbed parameters, their ecological state is assessed as "ecological regression".

Water of this quality is not suitable for drinking water supply, as well as for technical purposes, as it has an active destructive power to damage the water supply system and all the mechanisms and devices that serve it.

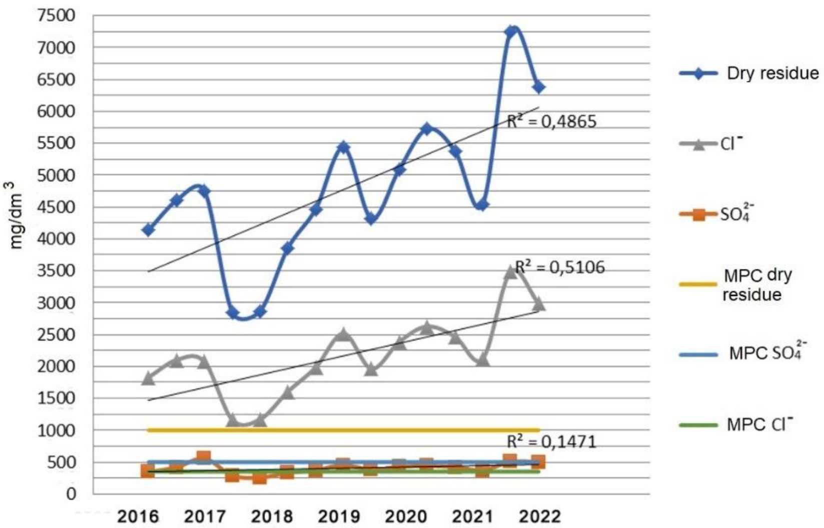

Fig. 4. Trends of dry residue, sulfates and chlorides

So, the biggest water pollutants are: dry residue, chlorides, increased water hardness, which is accompanied by a decrease in water transparency, as well as a deterioration of the oxygen regime. Water pollution and reduction of its quality mainly occur due to substances of anthropogenic origin. Pollutants enter water bodies with sewage, polluted surface runoff, with intensive erosion of the territory, which is largely plowed for agricultural land, after which the water is not suitable for drinking.

Analyzing the obtained results according to the salt criterion, we note that Buzky Estuary belongs to the IV quality class, that is, the water is dirty. According to the chemical tropho-saprobiological criterion, the average value of water quality was obtained – III, the water is slightly polluted. According to the criterion of toxic and radiation effects, the level of pollution of Buzky Estuary is assessed as "satisfactory", the water is slightly polluted.

The obtained results of the evaluation of the ecological state of surface water are also presented in the form of an ecological quality index (*EQI*) according to the EU Water Framework Directive 2000/60/EC [20]. According to this document, the quality class of Buzky Estuary surface water within Mykolaiv city is "poor". There is a steady trend towards regression.

4. Conclusions

The process of assessing the state of surface water resources included the analysis of the components of the salt composition, namely chlorides and sulfates. The trophic-saprobiological (ecological-sanitary) index was determined taking into account the absolute values of indicators: suspended substances, pH, phosphates, dissolved oxygen, BOD_5. To determine the index of specific indicators of toxic action, the absolute values of the components were used: copper, zinc, oil products, etc. It was determined that the pre-war quality category by salt composition components was 6.1, which is less than in 2022 (6.5); according to tropho-saprobiological indicators (environmental and sanitary) − the pre-war period is 4.3, which is less compared to 2022 (5.0); according to specific indicators – in the pre-war period it is less and is 4.7 compared to 2022, when this index was 5.0.

All defined surface water quality classes correspond to the degree of pollution “dirty” or “very dirty” and the state “poor” or “very poor”. Water of this quality is not suitable for household use, as it has an active destructive power to damage the water supply system and all the mechanisms and devices that serve it.

References

BUWR of Southern Buh. (2023). Update of the staff of the Southern Bug Basin Council. Retrieved from http://www.buvr.vn.ua/.

Dynamika zaboru i vykorystannia vody po Mykolaivskii oblasti za 2006–2015 rr. (2016). Mykolaiv.

Dynamika zaboru i vykorystannia vody po Mykolaivskii oblasti za 2015–2020 rr. (2021). Mykolaiv.

Common Implementation Strategy for the Water Framewormk Directive (2000/60/EC). (2003). *Guidance document No. 10 River and lakes – Typology, reference conditions and classification systems*. Retrieved from https://circabc.europa.eu/sd/a/06480e87-27a6-41e6-b165-0581c2b046ad/Guidance%20No%2013%20-%20Classification%20of%20Ecological%20Status%20(WG%20A).pdf

Hrytsenko, A. V., Vasenko, O. H., & Vernichenko, H. A.(2012). *Metodyka ekolohichnoi otsinky yakosti poverkhnevykh vod za vidpovidnymy katehoriiamy*. Kh.: UkrNDIEP.

Khilchevskoho, V. K. (2009). *Vodni resursy ta yakist richkovykh vod baseinu Pivdennoho Buhu*. K.: Nika-tsentr.

Mitryasova, O., Shybanova, A., & Dzhumelia, E. (2022). Prognosis Models of Nitrates and Orthophosphates Content in Surface Waters. *Environmental safety and nature management*, *4*(41), 33–44. doi: https://doi.org/10.32347/2411-4049.2022.4.30-43

Mitryasova, O., Pohrebennyk, V., Shybanova, A., & Nosyk, A. (2022a). Prognosis models of surface water status. *Water Supply and Wastewater Disposal: Monografie*. Politechnika Lubelska.

Mitryasova, O., Mariychuk, R., Shybanova, A., & Dzhumelia, E. (2022b). Prognosis Models of Nitrates and Orthophosphates Content in Surface Waters. *Proceedings of the 13th International Annual Conference “Global Environmental Development & Sustainability: Research, Engineering & Management”*, (November 17–18, 2022, Budapest, Hungary, Obuda University.

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Mykolaivskii oblasti u 2020 r. (2020). Rehionalnyi ofis vodnykh resursiv v Mykolaivskii oblasti, Mykolaiv. Retrieved from https://mepr.gov.ua/wp-content/uploads/2023/04/Regionalna-dopovid-Mykolayivskoyi-oblasti-2021-rotsi.docx

Romashchenka, M. I., Khvesyka, M. A., & Mykhailova, Yu. O. (2015). *Vodna stratehiia Ukrainy na period do 2025 roku (naukovi osnovy)*. K.: Comprint. Retrieved from http://iwpim.com.ua/wp-content/uploads/2015/10/11_03_2015.pdf

Rybalova, O. V. (2011). A comprehensive approach to determining the ecological status of small river basins. *The problems of environmental protection and ecological safety*, *XXXIII*, 88–97.

Vasenko, O. H., Vernychenko-Tsvetkov, D. Yu., & Kovalenko, M. S. (2008). Ecological assessment of the state of surface waters of Ukraine taking into account regional hydrochemical features. *UkrNDIEP*, 36–53.

Voda pytna: vymohy ta metody kontroliuvannia yakosti, DSTU 7525:2014 (2014). Retrieved from https://zakon.isu.net.ua/sites/default/files/normdocs/1-10672-dstu_voda_pytna.pdf

Vodna stratehiia Ukrainy do 2050 r.: Rozporyadzhennyam Kabinetu Ministriv Ukrayiny 2022, No. 1134-r. (2022). Retrieved from https://zakon.rada.gov.ua/laws/show/1134-2022-%D1%80#Text

Water Code of Ukraine: Law of Ukraine dated 1995, № 213/95-VR. (1995). Retrieved from http://zakon2.rada.gov.ua/laws/show/213/95-%D0%B2%D1%80

Water resources of Mykolaiv region. (2023). Retrieved from http://fishing-ua.org.ua/mykolaivska/