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IMPROVING MONITORING OF WATER QUALITY CHARACTERISTICS IN ARTIFICIAL WATER STORAGE FACILITIES IN UKRAINE

The object of research is the hydroecological situation in the surface waters of Ukraine, indicated by the data of modern monitoring of surface waters, especially in the part of the Dnipro basin that forms the Kremenchuk Reservoir. Ukraine has not formed a holistic system of measures for monitoring and maintaining the quality of surface waters and state supervision over diseases associated with drinking water. The qualitative characteristics of drinking water are determined by the ecological state of the surface water bodies that are sources of drinking water. Therefore, this work is devoted to determining the need and ways to improve the state monitoring of the qualitative characteristics of waters in artificial water-accumulating objects and parts of the river basins that form them.

The work uses scientific methods of systemic analysis, generalization and systematization, takes into account synergistic approaches in hydroecology and consideration of possible development scenarios based on the autopsy method. It is shown that diagnostic water monitoring covers only a small part of water bodies in Ukraine, and the modern hydrological monitoring network of Ukraine has up to 400 posts, including chemical pollution in half of the points, which is not enough. The state of the legal field of development of the water strategy of Ukraine, the monitoring mission of the state and the implementation of the legislative framework of Ukraine to EU requirements are analyzed, but the state of surface waters in Ukraine encourages to study the experience of water protection in European and world countries. This experience indicates that in the field of monitoring and protection of surface waters in Ukraine, a much higher and more accurate level of monitoring and a more stringent level of state regulation of water relations towards greening are needed.

The work develops a structural and logical scheme of factor analysis, including systems of hydro-ecological monitoring of the formation of the aquatic environment of part of the Dnipro basin in the Kremenchuk Reservoir area. The need for systematic improvement of monitoring of water quality characteristics in artificial water storage facilities, which is the Kremenchuk Reservoir, and the need for a significant concentration of monitoring points, both in the reservoir and in the Dnipro basin that forms it, has been identified. A change in monitoring points and systematic diagnostics of reservoirs using modern capabilities of satellite sounding of water bodies within the framework of the greening of water relations in Ukraine has been proposed.

Keywords: *hydroecological situation, surface waters, artificial water storage facilities, water directives, Kremenchuk Reservoir.*

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1. Introduction

In Ukraine, like nowhere else in Europe, during the Soviet era, the destruction of natural aquatic ecosystems reached a critical point and only current monitoring will allow to outline ways to revitalize aquatic ecosystems.

The importance of factor analysis and monitoring of water resources is constantly growing and is determined by global environmental trends of geopolitical importance and local problems of access to clean water for the population, both in the world and in Ukraine.

A number of scientists have devoted their scientific works to the study and improvement of monitoring and assessment of the natural and anthropogenic components of water systems, and especially reservoirs. Scientists around the world are constantly studying the problem of monitoring and revitalization of surface water bodies, developing adaptation measures for the shortage of fresh water in the face of climate change [1]. Thus, scientists from China and the USA have found that the negative anthropogenic impact on annual runoff is greater than climate change [2]. The topical issues of the implementation of European standards for monitoring and quality and safety of drinking water are especially studied regarding the need to update water and sanitary legislation, and the study of toxic compounds in the field of water supply [3]. Strategies for making management decisions to improve the ecological state of lakes and cooling ponds are also developed and proposed [4–8]. Certain aspects of integrated water resources management are considered, both at the national level and at the river basin level [5]. Certain aspects of ecological and hydromorphological approaches to justifying the protection of reservoir banks and zoning of banks are studied [6, 7].

But the following are not sufficiently studied:

– algorithms for holistic assessment and selection of key indicators for monitoring diagnostics of the aquatic ecosystem of reservoirs;
– correlation interdependence and mutual influence of chemical and biological processes and hydrological conditions in reservoirs;
– indices of ecological sustainability and sustainable development of the reservoir ecosystem;
– Geographic Information System (GIS) – analysis and standards for remote sensing of the ecosystem of reservoirs and the basin;
– problems of adapting monitoring indicators to the EU standards and standards for assessing the aquatic environment;
– correlation analysis and processing of index indicators of water quality in water sources (especially reservoirs), to the quality of drinking water for consumers after treatment.

The situation in Ukraine, as indicated by state monitoring data [9], remains complex: in the waters of the Dnipro basin, rivers flowing into the Kremenchuk Reservoir, the following are detected:

– pesticides (acetochlor, terbuthylazine, chlorpyrifos);
– polyaromatic hydrocarbons (fluoretten, benzopyrene, etc.);
– pharmaceuticals (triclosan);
– heavy metals (zinc, cadmium, etc.).

Ukraine has not revised the system of measures and surveillance for water-related diseases, as required by Art. 8 of the "Protocol on Water and Health in Ukraine for 2019–2030", to implement the Water Strategy of Ukraine for the period until 2050, within the framework of the "EU Water Initiative Plus" project [10]. After all, only a significant change in the quality of surface waters will have a positive impact on the quality of drinking water in Ukraine.

Therefore, *the aim of research* is to improve state monitoring of the quality characteristics of waters in artificial water storage facilities and parts of the river basins that form them.

2. Materials and Methods

The work used scientific methods of system analysis, generalization and systematization, took into account synergistic approaches in hydroecology and consideration of possible development scenarios based on the abduction method.

Thus, the legal imperatives of Ukraine's implementation of the EU Water Framework Directive, and annual water monitoring programs, methods and classifications of ecological and chemical melting of surface water bodies were systematically analyzed.

The components and objects of land and water monitoring, indicators of comparative content of substances in drinking water, in relation to the requirements of the EU and Ukraine, were generalized and systematized. Synergetics, i. e. the combination of individual factors and factors on the state of surface waters, were taken into account.

Possible scenarios for the development of hydrological monitoring of complex ecological hydrosystems, such as the Kremenchuk Reservoir, were determined. Scientific abduction methods allowed to propose a change in the mission of monitoring and diagnostics of reservoirs and to form a structural and logical scheme of the spatial monitoring base of the Kremenchuk Reservoir.

3. Results and Discussion

The functions of diagnostic monitoring of surface waters, including water quality control, are performed by:

– The State Service of Ukraine for Food Safety and Consumer Protection;
– The Centers for Disease Control and Prevention (CDC) of the Ministry of Health of Ukraine, whose competence includes monitoring the quality of water and water bodies of categories I and II.

Having ratified the EU Water Framework Directive in 2014, Ukraine undertook to change the norms, standards, methods and procedures for water monitoring. This was reflected in the Resolution of the Cabinet of Ministers of Ukraine No. 758 of September 19, 2018 "Procedure for State Water Monitoring", which entered into force on January 1, 2019 [11].

In Ukraine, in accordance with the Order of the Ministry of Health of May 12, 2019 No. 400, the State Sanitary Norms and Rules (DSanNiP) for drinking water were approved [12].

The orders of the Ministry of Environment approve annual water monitoring programs, for example, the "Program of State Monitoring of Surface Waters for 2022" [13], which provided for 583 monitoring points.

During the study, more attention was focused on indicators of the ecological state of surface waters, rather than drinking water, because clean water and drinking water are different environmental standards. But the quality characteristics of drinking water, especially in wells, are determined by the ecological state of surface water bodies, which needs to be improved.

The state monitoring of the natural environment of Ukraine has three components: diagnostic, operational, and research.

Ukraine has also introduced a methodology and classification of the ecological and chemical state of a surface water body, the ecological state of surface water, including artificial and significantly modified bodies, i. e. reservoirs.

In accordance with the provisions of the law, the Ministry of Ecology and Natural Resources approved a list of pollutants for determining the state of water bodies [14]. This list identifies 45 priority substances – pollutants, and provides for 5 classes of ecological and hydrological status: "excellent", "good", "satisfactory", "bad" and "very bad", and 2 classes of chemical status: "good" and "failure to achieve good".

The Ministry of Environmental Protection and Natural Resources of Ukraine, by its order "On Approval of State Water Monitoring Programs" [15] dated 31.12.2020 No. 410, determined both monitoring subjects and diagnostic and operational monitoring.

Diagnostic monitoring is carried out according to 70 indicators:

– physicochemical – 12;
– priority (pollutants) substances – 37;
– specific basin substances – 10;
– additional indicators – 11.

State monitoring in the Kremenchuk Reservoir is carried out by the Regional Office of Water Resources in Cherkasy Region of the State Agency for Water Resources, the Middle Dnipro Basin Council, the State Environmental Protection Service, and the Center for Disease Control and Prevention.

Water withdrawal from the Kremenchuk Reservoir for various needs in 2022 amounted to 36.057 million m^3, which is 8 percent less than in 2021 [16].

However, the quality of drinking water, despite the concern of legislators for people's health, in Ukraine, using the example of Poltava Region, requires changes (Table 1).

The dynamics of detailed objective information about the state of the reservoir and river basins will allow to study the real state, but the main thing is to find the answer to what are the ways to prevent pollution and revitalize rivers and the reservoir itself. After all, the total amount of pollutants entering the surface massifs is huge (Table 2).

Table 1

Water quality of drinking water sources in Poltava region for 2022 [16]

No.	Water samples that do not meet standards	% of total quantity	
		2021	2022
1	In general:		
	sanitary and chemical indicators	12.2	10.7
	bacteriological	10.1	2.5
2	Underground sources:		
	sanitary and chemical indicators	5.8	37.9
	bacteriological	5.3	3.3
3	Sources of decentralized water supply:		
	sanitary and chemical indicators	35.1	41.7
	bacteriological	9.0	28.2

Table 2

Return (waste) water discharges in Ukraine for 2021–2022 [16]

No.	Volumes of discharged return waters, million m^3	2021	2022
1	Polluted	541	374
2	Without treatment	119.3	79.9
3	Insufficiently treated	422.2	294.1
4	Standard-treated	1430	1550
5	Standard-clean without treatment	2713	1550
Total:		4684.6	2979.5

If to compare the structure of the quality characteristics of wastewater in Ukraine and in the EU countries, these are significantly different indicators.

According to the national report on the quality of drinking water and the state of drinking water supply and wastewater disposal in Ukraine in 2022 [16]:

– 2.98 billion m^3 of wastewater was discharged;
– 1.3 billion m^3 passed through treatment plants;
– 1.05 billion m^3 or 31.6 % underwent complete biological treatment;
– 374.5 million m^3 of polluted return water was discharged.

In the Kremenchuk Reservoir, if the biogenic indicators are within normal limits, then an excess of organic pollution is observed:

– biochemical oxygen demand (BOD_5), which is equal to 2.0–7.4 mg O_2/dm^3;
– chemical oxygen demand (COD), which is equal to 30.0–46.8 mg O_2/dm^3;
– exceeding the quality standards for mercury content by 1.1–4.5 times [16].

The importance of monitoring and protecting freshwater in countries around the world is even emphasized by the celebration of World Water Monitoring Day (WWMD) on September 18, 2003. This day was established by the American Clean Water Foundation, within the framework of the Program on public participation in the protection of water resources (Clean Water Act) [17].

US citizens are encouraged to independently conduct basic water monitoring in local water bodies. Kits are distributed that allow for water quality analysis: temperature, acidity (pH), turbidity and dissolved oxygen.

Since harmful substances act synergistically (synergistically), the EU countries have come to the conclusion that integrated environmental monitoring indicators indicate changes in the ecological balance of the system of natural complexes:

– balance, as the ratio of primary and secondary bioproductivity;
– productivity, as the rate of bioproductivity to biomass;
– intensity of nutrient turnover.

The European Environment Agency (EEA) defines five groups of integral monitoring indicators [18]:

– A_1 – descriptive indicators, for example, the share of protected areas, the area of organic land, forestation of territories, plowing, and others;
– B_1 – indicators of the implementation of the intended directorate goals;
– C_1 – efficiency indicator, water capacity, level of carbon emissions per 1 million EUR of GDP;
– P_1 – indicators of political effectiveness, as an effective regulatory policy of measures on the state of the environment;
– E_1 – indicator of the well-being and well-being of the population of the country (region).

Land monitoring, both in Ukraine and in countries around the world, overlaps with monitoring of water bodies and waters (Table 3).

Countries around the world are constantly improving indicators of water quality diagnostics. Thus, in the EU Directive 2020/2184 on the quality of drinking water intended for consumption, a new indicator has appeared: bisphenol A – as a compound that negatively affects the endocrine system of the body, the main source: plastic bottles [19]. In most countries of the world, plastic bottles are prohibited for feeding children, and for the EU a standard of 2.5 μg/l of bisphenol has been set, or 25 times lower than in Ukraine [19].

Association Agreement Ukraine the EU has incorporated 6 directives on water quality and regulation of water relations to achieve EU water standards [20]. This is due to the fact that Ukraine is a water-scarce country, and production standards for water capacity are outdated, as are outdated technologies for wastewater treatment of sewage systems.

In Ukraine, in order to implement the European standards of water relations and ensure the quality of drinking water, an open monitoring project for drinking water quality is in operation [21]. Within the framework of the project, four certified laboratories at the EU level, as well as laboratories of the National Academy of Sciences and Universities, such as the laboratory of the Dumansky Institute of Colloidal Chemistry and Water Chemistry of the National Academy of Sciences of Ukraine, are working and operating in Ukraine.

Table 3

Comparative table of components and objects of land and water environmental monitoring*

Ukrainian		Foreign
Land	Water	(features)
Monitoring of soils, contamination by heavy metals, radionuclides	Surface waters	Indicative water quality parameters: – microbiological; – chemical; – physical
Observance of the regime of water protection zones	Monitoring of actual levels and maximum permissible	Federal water quality assessment, public control and monitoring
Identification of pollutants	Aquatic bioresources	Ecological understanding of water quality
Directions and development of negative processes	Coastal waters and zones	Integrated ecological and hydrological observations
State of lands, analysis of the ecological state of lands	Groundwater, objects and their parts	Integrated hydroecological monitoring
State of coastlines of rivers, seas, lakes, bays, reservoirs, hydraulic structures	Groundwater zones (territories)	–
Land erosion processes	–	–
State of lands of settlements	–	–
Geoinformation assessment of aerospace information	–	–

Note: * compiled by the authors from available sources

Automatic water quality control stations (AWQCS) are devices that can adapt, process, store and transmit information. Analyzers can also be installed – devices that determine the chemical composition and properties of water on site (maximum permissible concentrations – MPC), when a particular substance is exceeded, the water is considered unsuitable.

Substances in different concentrations form different signs of harmfulness (limiting sign of harmfulness – LSH) of action and general harm.

In the EU, water quality indicators are more demanding than in Ukraine, so the maximum permissible hardness is 1.2 mmol/dm^3, the narratives of the World Health Organization are even more demanding (Table 4).

Only in terms of indicator indicators in waters, regarding substances of epidemic safety, the state standards of Ukraine: DSanNiP – 2.2.4.171.10, meet the requirements and standards of Directive 98/83/EC [22].

Six EU water directives indicate the introduction of a modern system of water ecological and hydrological monitoring, and the implementation of infrastructure projects. These projects are aimed at a significant change in the hydromorphological characteristics of water bodies, and the development of a network of chemical laboratories for ecological monitoring of waters [22].

Taking into account the above factors, European countries have introduced indicative monitoring parameters for assessing the state of water bodies and especially at points of pollution sources by type: microbiological; chemical; physical, including indicators of thermal pollution.

Monitoring parameters indicate monitoring the state of water in Europe not relative to the maximum permissible levels, as in Ukraine, but to the minimum permissible ones. Especially, regarding dry residue, hardness, total iron, turbidity, sulfates, chlorides, aluminum, both in terms of organoleptic and toxicological indicators.

Table 4

Comparative content of substances in drinking water for Ukraine and EU countries*

Substance	Ukraine	EU	Exceeding standards
Total hardness:			
aluminum	3–4 mmol/dm^3	1.2	3 times
nitrogen	3–4 mmol/dm^3	1.2	2.5 times
manganese	3–4 mmol/dm^3	1.2	4 times
sulfates	3–4 mmol/dm^3	1.2	2 times
arsenic	3–4 mmol/dm^3	1.2	5 times
chloride	3–4 mmol/dm^3	1.2	30x
silver	–	not allowed	–
beryllium	–	not allowed	–
nickel	–	not allowed	–
strontium	–	not allowed	–
23 indicators:			
acrylamide	absent	normalize	100 times
vinyl chloride	absent	normalize	100 times
epichlorohydrin	absent	normalize	100 times
chlorates	absent	normalize	100 times

Note: * compiled by the authors from available sources

The requirements of the European Water Framework Directive are closely related to the EUUROWATERNET system.

Integration into the EU is a movement towards the revitalization of aquatic ecological systems and water bodies.

Key monitoring indicators certainly determine the state of water bodies the most. The negative impact of thermal pollution is certainly an important aspect, but it is necessary to determine the main key most significant indicators.

The main assessment of pollution in surface waters is organoleptic indicators. For example, in drinking water, these indicators will allow to detect 72 % of pollution and indicators of the physical state of water perceived by the senses. Organoleptic – control and generalization of water quality has disadvantages: low variability and high subjectivity.

Organoleptic indicators are divided into:

– smell (5-point scale) – 1 – not determined; 2 – felt, as if to inform; 3 – felt without warning; 4 – felt very well; 5 – strong smell;
– taste (has no taste);
– transparency (30 cm layer of water makes it possible to read the font);
– turbidity.

Organoleptic indicators are correlated with most water quality indicators, especially sanitary-chemical, bacteriological, physico-chemical.

Despite the natural pollution of the water of rivers and streams, including the Dnipro, surface waters of Ukraine should have organoleptic indicators that indirectly indicate clean water and the visuality of water pollution. Such indicators are when watercourses and reservoirs are saturated with substances in such quantities that worsen water quality.

The mineralization of surface waters is defined as the content of salts in water. On the one hand, an insufficient amount of minerals in water can cause systemic diseases, with the leaching of salts from the body. On the other hand, a high concentration of minerals, disrupting biochemical and metabolic processes, negatively affects living organisms.

The Dnipro River and its tributaries have a naturally high-water mineralization, which ranged from 0.54 to 0.720 g/dm^3 [23].

The main key indicator is also dissolved oxygen in water, as the main indicator of the ecological state of the reservoir.

The optimal indicator is 5–14 mg/dm^3, but if the oxygen content reaches a level below 4 mg/dm^3, fish die.

Dissolved oxygen enters water in the form of O_2 molecules, enters during the process of absorption, release by vegetation and arrival with rain and meltwater, and is consumed due to the oxidation of organic and chemical. Analyses indicate that even daily fluctuations in oxygen content can amount to 2.5 mg/dm^3. The seasonal factor is of a stratification nature. But the lowest oxygen content is in water bodies and reservoirs that are polluted and eutrophicated.

The Wikler method is quite relevant when dissolved oxygen reacts with freshly deposited Mn(II) hydroxide.

But for natural water bodies, the key indicator is biological oxygen consumption – this is the amount of oxygen consumed by organic compounds present in water, for example, for 5 days in 1 liter of water, without access to light and air. An important indicator is chemical oxygen demand (COD) – this is the amount of oxygen in milligrams or grams per 1 liter of water, necessary for carbon-containing substances.

On the one hand, the regulation of the Dnipro tributaries flowing into the reservoirs significantly reduces the amount of sediment, soil and rock washout, and slows down siltation, leveling water accumulation and mineralization. On the other hand, increased evaporation reduces the total water content, and the concentration of water mineralization increases.

A key indicator that we do not pay enough attention to is the increased nitrogen input due to intensive use in agriculture in surface and groundwater. This indicates a 10-fold increase in various forms of nitrogen compounds in well water in the Poltava region over the past 10 years [16]. Significant nitrogen accumulation in groundwater does not decrease even with a significant reduction in fertilizer application over 5 years.

The accumulation of nitrogen in the waters of rivers, swamps and ponds, as well as in the Dnipro reservoirs leads to eutrophication of water bodies, algae blooms, and the death of organisms. Scientists have studied that in order for the Rhine to reach the level of indicators of 1970, it was necessary to almost completely stop the application of nitrogen compounds to fields in the Rhine River basin for 15 years [24].

Anthropogenic eutrophication is promoted by four types of sources of pollution of surface water mineralization with phosphorus and nitrogen compounds and other elements:

1) *urbogenic sources*: untreated wastewater from settlements;

2) *agrogenic sources*: runoff from fields and reclaimed areas;

3) *zoogenic sources:* livestock, manure;

4) *technogenic* sources: runoff from aquifers, industrial wastewater.

Water monitoring regulations: are also a determining aspect of the objectivity of the qualitative and quantitative assessment of the ecological and hydrological state of the aquatic environment in the territory and individual water bodies.

Approved on September 19, 2018, No. 758 "Procedure for State Water Monitoring" [11] defines the regulations for conducting:

– diagnostic monitoring:

a) the first year;

b) the first two years;

c) the fourth year;

– operational monitoring of drinking water sources during the year for the use of more than 100 m^3 of water per day for domestic purposes (annually), in the period between diagnostic monitoring;

– research monitoring for surface water bodies (continuously).

The ecological situation indicated by the data of modern water monitoring, especially at the Kremenchuk Reservoir, remains difficult. Ukraine has not revised the system of measures to maintain the quality of surface water and monitor water-related diseases. The qualitative characteristics of drinking water consumed by the population from wells and reservoirs are determined by the ecological state of surface water bodies.

Domestic, industrial, and agricultural discharges cause chemical, physical, biological, and thermal pollution of the hydrosphere in the Kremenchuk Reservoir area.

Monitoring points for water diagnostics should be locally systematically connected using software products such as the Prophet software package, which provide a dynamic model of the increase (decrease) of jumps in identified trends with increments, especially when it is possible to see a monotonous increase in pollution.

Observation points for the significance of a water body are divided into 4 categories:

1) especially important watercourses and reservoirs;

2) water bodies in areas of cities and towns, in places of collector and drainage water discharge, on the border and end reaches of rivers;

3) water bodies with low and moderate load;

4) on unpolluted water bodies (background areas).

Kremenchuk Reservoir, as a first category facility, where daily observations are conducted at the points according to the abbreviated program – 1, in the sections after discharges water (5 l) is stored for 5 days. Sub-decadal sampling according to program 2, monthly, according to program 3, and a mandatory program in the main phases of the water regime of the reservoir.

Ecological and hydrological monitoring of the reservoir should be formed within the part of the basin that forms and affects the Kremenchuk Reservoir.

The development of monitoring and management of surface water bodies is shown in Fig. 1.

The methodological integrity of the algorithm for monitoring and assessing natural and anthropogenic components of systems in reservoirs, the algorithm for holistic assessment and selection of key index indicators for monitoring diagnostics of the water ecosystem of the reservoir are proposed to be improved, according to the scheme shown in Fig. 2.

Changing the mission of monitoring and diagnostics of reservoirs in Ukraine, it is necessary to change the Water Code, adapting and implementing the EU water legislation into the legislation of Ukraine, namely:

– clarifying terms and definitions;

– changing the boundary standards of water protection zones not according to the water body in meters, but defining the zones by the boundaries of the river floodplain, making changes to the law on land management and the relevant Resolutions of the Cabinet of Ministers;

– implementing restrictive norms for the use of potent herbicides and pesticides, detergents and other chemicals in agriculture, industry and everyday life.

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The number of monitoring points and the frequency of water analysis were reduced. The monitoring network was expanded by installing points in potentially polluted areas, such as stream beds, collectors from under treatment plants and the mouths of the rivers Supii, Zolotonoshka, Irklii, Bataley, Sula, Kryva Ruda on the left bank, as well as in 17 wastewater streams from the city of Cherkasy that flow into the Kremenchug reservoir from the right bank. These points will provide an objective picture of the pollution entering the Kremenchug Reservoir, including thermal pollution, in accordance with the monitoring base (Fig. 2).

Diagnostics of the ecological state of a surface water body are carried out according to biological, physicochemical, chemical and hydromorphological indicators. But the coverage of the water body by monitoring must be holistic.

Diagnostic monitoring of the Kremenchuk Keservoir must cover the entire Dnipro River basin with a network of points, which forms the flow into the reservoir and diagnose the state of hundreds of surface water bodies in terms of tributaries, treatment facilities, reservoirs, water sources and watercourses.

Monitoring points must be placed not only in the reservoir, but also within the Dnipro River sub-basin, for example, on the rivers: Supii, Zolotonoshka, Irklii, Bataley, Sula, Kryva Ruda on the left bank, in accordance with the hydrographic and water management zoning of the territory of Ukraine.

The state of the reservoir is also adversely affected by discharge and wastewater, in which chemical compounds and organic substances are dissolved, from urbanized areas. There are two types of water: discharge and wastewater:

– discharge water – water diverted as a result of hydromelioration;
– wastewater – water formed as a result of industrial and domestic activities, as well as the runoff of polluted precipitation from the territory of cities, roads, and industrial zones.

Scientists have developed a methodology for ecological and hydrological monitoring of reservoirs (EPMK) and described an ecosystem approach to water monitoring, because the current monitoring does not sufficiently take into account the ecological aspects of the functioning of such a complex system as the Kremenchuk Reservoir [6].

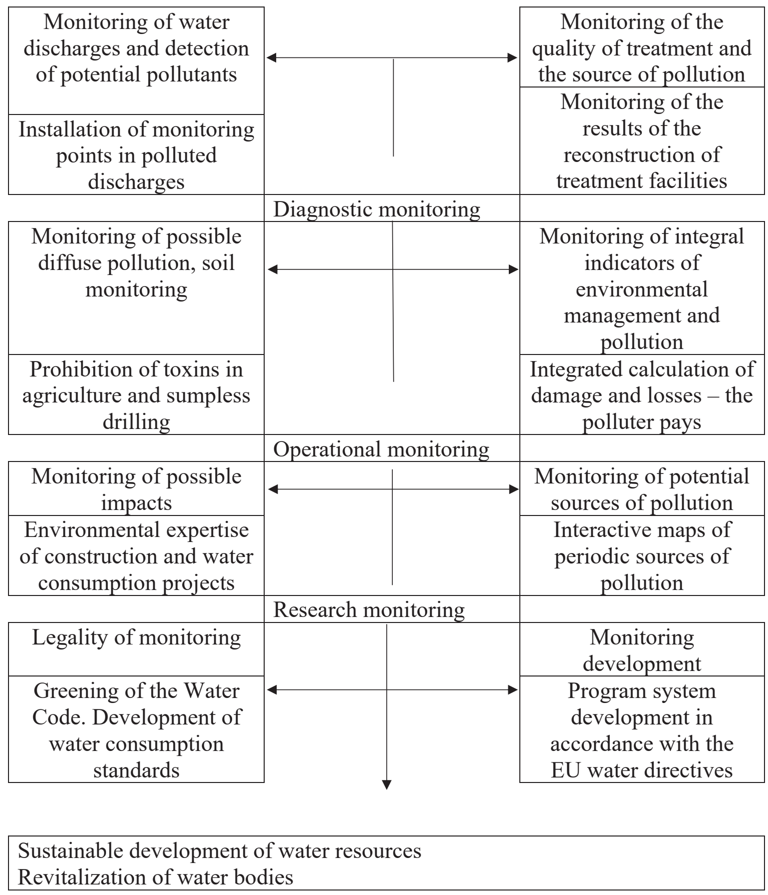

Fig. 1. Development of monitoring and management of surface water bodies

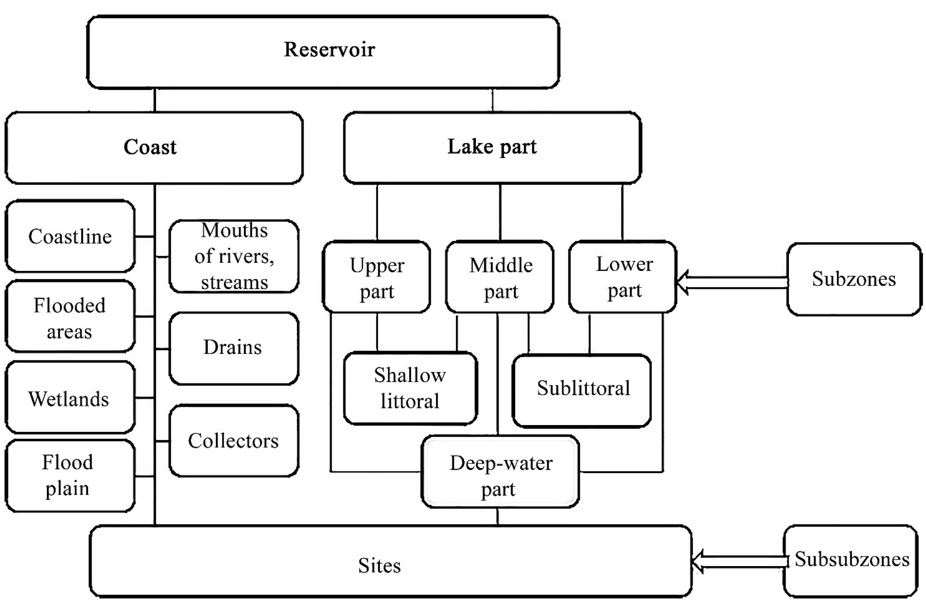

Fig. 2. Structural and logical diagram of the spatial monitoring base of the Kremenchuk Reservoir

In time, EU scientists and ecologists determine the control of nonylphenol, with a standard of 0.3 μg/l and beta-estradiol ng/l, that is, the world is bringing the quality of water supply and water use to the level of accuracy of nanotechnology. EU experts have also identified a list of additional substances to monitor, especially for pharmaceuticals, and this list is constantly being updated, with perfluoroalkyl and polyfluoroalkyl substances (PFAS), being included in the regulatory control list from 2021, with a PFAS standard of up to 0.1 μg/l [25].

Also included in the list of controlled substances are haloacetic acids (monochloro-, dichloro- and trichloroacetic, mono- and dibromoacetic acids).

These acids are formed when water is disinfected with chlorine compounds with trihalomethanes. Until 2021, these acids were ignored, but now in the EU they must be removed from drinking water.

Monitoring of discharge waters should be implemented in the surface water bodies of irrigation sites, for example, three bodies of the Hradizhsk irrigation system, and at the points of discharge of drainage water from the irrigation systems (Fig. 2) into the reservoir.

The results of the study should be finalized in terms of specifying the location of surface water monitoring points in the watercourses of the Kremenchuk Reservoir, especially possible thermal pollution.

Martial law conditions significantly limited the volumes of state and municipal monitoring of surface water bodies due to underfunding of fences and surface water analysis, especially by services independent of water consumption.

Prospects for further research require expeditionary work directly on reservoirs and in the basins of small rivers that shape the water quality in reservoirs.

The above analysis of the monitoring mission identified areas for improving the development of monitoring:
- algorithm for a holistic assessment of the state;
- indicative indicators;
- integrated ecological and hydrological indicators;
- change of the monitoring base;
- selection of key indicators;
- automation of discharge monitoring;
- methods of assessing diffuse pollution (monitoring wells);
- water monitoring regulations;
- strengthening of environmental assessment;
- GIS analysis and zoning;
- indices of ecological sustainability;
- complex hydroecological monitoring.

That is, the algorithm of a holistic basic assessment of the state of surface waters is determined based on the structural and logical scheme (Fig. 1), which presents the placement of monitoring points (project) in the sections of rivers, canals, irrigation systems, streams, drains, collectors, etc. (Fig. 2). It is necessary to change the monitoring base, that is, to thicken the monitoring points by more than 100 times, using data from satellite sensing of the earth's surface.

This will allow to cover and create a monitoring base and form a model of impacts in the reservoir, stop and prevent negative impacts.

4. Conclusions

The study shows that the ecological situation indicated by the monitoring data of surface waters at the Kremenchuk Reservoir requires measures to maintain water quality. The state of surface waters in Ukraine encourages the study and implementation of the experience of surface water protection in European countries. This experience indicates that in Ukraine it is necessary to organize a much higher and more accurate level of monitoring and a more stringent level of state regulation of water relations towards ecologization.

The need for a significant concentration of monitoring points, both in the Kremenchuk Reservoir and in the Dnipro basin that forms it, including using satellite sounding data of the earth's surface, has been identified.

The proposed structural-logical scheme of factor analysis, including systems of hydro-ecological monitoring of the formation of the aquatic environment in the Kremenchuk Reservoir area, can serve as a basis. The regulation of the frequency of monitoring needs to be developed and constantly improved. The greening of monitoring assessments requires not only an algorithm for a holistic assessment of the state, but also the use of indicative indicators (key), but also integral ecological and hydrological indicators. The preparatory base of ecological and hydrological analysis based on integral monitoring indicators is able to provide GIS analysis of the studied object.

The need to replace the MPC indicators with indicative indicators of the quality of surface, groundwater and drinking water, defined by the EU Water Directives, is noted. The development of monitoring of factors influencing the state of surface waters requires constant scientific research and funding of research on improving the development of water relations and water monitoring.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

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Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating this work.

References

1. Bates, B. C., Kundzewics, Z. W., Wu, S., Palutukof, J. P. (2008). Climate Change and Water. *Technical Paper of the Intergovernment Panel on Climate Change. IPCC Secretariat*. Geneva, 210.
2. Wang, H., Chen, L., Yu, X. (2016). Distinguishing human and climate influences on streamflow changes in Luan River basin in China. *CATENA, 136,* 182–188. https://doi.org/10.1016/j.catena.2015.02.013
3. Pronevych, O. S. (2017). Implementation of European Standards for the Quality of Drinking Water: The Institutional and Legal Aspect. *Forum prava, 3,* 182–189. Available at: http://nbuv.gov.ua/UJRN/FP_index.htm_2017_3_33
4. Klymenko, M. O., Klymenko, O. M., Petruk, A. M. (2013). Hidrolohichnyi monitorynh vodnykh ekosystem z ohliadu na suchasni Yevropeiski napriamy u pryrodookhoronnii diialnosti. *Visnyk Poltavskoi derzhavnoi akademii, 3,* 22–27.

ISSN-L 2664-9969; E-ISSN 2706-5448

5. Pinchuk, O. L., Herasimov, Ye. H., Kunytskyi, S. O. (2019). *Dyrektyvy YeS u sferi upravlinnia vodnymy resursamy.* Rivne "Volynski berehy", 224.
6. Dubniak, S. S. (2006). Metodolohiia doslidzhennia strukturno-funktsionalnykh osoblyvostei rivnynnykh vodoskhovyshch. *Hidrolohiia, hidrokhimiia i hidroekolohiia, 10,* 20–35.
7. Kampa, E., Ward, J. G., Leipprand, A. (2007). *Convergences with EU Water Policies.* Available at: https://www.ecologic.eu/2652
8. Klymenko, M. O., Vozniuk, H. I., Verbetska, K. Yu. (2012). Porivnialnyi analiz normatyviv yakosti poverkhnevykh vod. *Naukovi dopovidi NUBi P, 8 (30).*
9. *Dani derzhavnoho monitorynhu poverkhnevykh vod. Derzhavne ahenstvo vodnykh resursiv Ukrainy.* Available at: https://data.gov.ua/dataset/surface-water-monitoring
10. *Vodna initsiatyva YeS plius dlia krain Skhidnoho partnerstva* (2021). Available at: https://www.euwipluseast.eu/images/2021/07/PDF/EUWI_UA_PublicConsultation_Toolkit_Ukr.pdf
11. *Poriadok zdiisnennia derzhavnoho monitorynhu vod* (2018). Postanova Kabinetu Ministriv Ukrainy No. 758. 19.09.2018. Available at: https://zakon.rada.gov.ua/laws/show/758-2018-%D0%BF#Text
12. *Pro zatverdzhennia derzhavnykh sanitarnykh norm ta pravyl "Hiiienichni vymohy do vody pytnoi, pryznachenoiu dlia spozhyvannia liudynoiu"* (2010). Nakaz Ministerstva okhorony zdorovia No. 400. 12.05.2010. Available at: https://zakon.rada.gov.ua/laws/show/z0452-10#Text
13. *Prohrama derzhavnoho monitorynhu poverkhnevykh vod na 2022 rik* (2023). Nakaz Ministerstva zakhystu dovkillia ta pryrodnykh resursiv No. 1. 05.01.2023. Available at: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=97103
14. *Perelik zabrudniuiuchykh rechovyn dlia vyznachennia khimichnoho stanu masyviv poverkhnevykh i pidzemnykh vod ta ekonomichnoho potentsialu shtuchnoho abo istotno znyzhenoho masyvu poverkhnevykh vod* (2017). Nakaz Ministerstva ekolohii ta pryrodnikh resursiv Ukrainy No. 45. 06.02.2017. Available at: https://zakon.rada.gov.ua/laws/show/z0235-17#Text
15. *Pro zatverdzhennia prohram derzhavnoho monitorynhu vod* (2020). Nakaz Ministerstvo zakhystu dovkillia ta pryrodnykh resursiv No. 410. 31.12.2020. Available at: https://mepr.gov.ua/nakaz-mindovkillya-410-vid-31-12-2020/
16. *Natsionalna dopovid pro yakist pytnoi vody ta stan pytnoho vodopostachannia v Ukraini u 2022 r.* Available at: https://mtu.gov.ua/content/nacionalna-dopovid-pro-yakist-pitnoi-vodi-ta-stan-pitnogo-vodopostachannya-v-ukraini.html
17. *Safe Drinking Water Act,* 42 U.S.C.&& 300f-300-f-26.
18. EU Water Framework Directive 2000/60/EC (2000). *Official Journal of the European communities, 22.12.2000. L 327/1,* 118.
19. *Endocrine Disrupting Compounds* (2009). National Institutes of Health. U.S.Department of Health and Human Services.
20. *Uhoda pro Asotsiatsiiu mizh Ukrainoiu, z odniiei storony, ta Yevropeiskym Soiuzom, Yevropeiskym spivtovarystvom z atomnoi enerhii i yikhnimy derzhavamy-chlenamy, z inshoi storony* (2023). Verkhovna Rada Ukrainy. Dokument 984_011. 30.11.2023. Available at: https://zakon.rada.gov.ua/laws/show/984_011#Text
21. Berezhna, Yu., Kosohina, I. (2024). Bezpechna pytna voda v Ukraini: dostup do informatsii pro yakist vody ta metody vodo pidhotovky. *Resursy pryrodnykh vod Karpatskoho rehionu.* Lviv.
22. *Dyrektyva Rady 98/83/IeS vid 3 lystopada 1998 roku pro yakist vody, pryznachenoi dlia spozhyvannia liudynoiu.* Available at: https://zakon.rada.gov.ua/laws/show/994_963#Text
23. Hafiatulina, O. H., Okhrimenko, O. V. (2018). Monitorynh hidrokhimichnoho stanu richky Dnipro mista Kherson. *Tavriiskyi Naukovyi visnyk, 83,* 238–243.
24. Hofstra, M. (2010). *International cooperation on the river Rhine.* Unesco-IHE/Water Governance Centre NL.
25. *Pro tekhnichni rehlamenty ta otsinky vidpovidnosti* (2015). Zakon Ukrainy No. 124-VIII. 15.01.2015. Available at: https://zakon.rada.gov.ua/laws/show/124-19#Text

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