Spatio-Temporal Representation of the Ecological State of the Surface Waters of the Lower Section of the Dnieper River using GIS Technologies

Anastasiia Bystriantseva[1[0000-0003-0611-1548]], Iryna Shakhman[2[0000-0001-6204-4410]] and Maksym Bystriantsev[3]

[1]Kherson State University, 27 Universitetska st., Kherson, 73000 Ukraine
abystryantseva@ksu.ks.ua
[2]Kherson State Agricultural University, 23 Stretenskaya st., Kherson, 73000 Ukraine
shakhman.i.a@gmail.com
[3]Teaching and Educational Complex "School of Liberal Arts" of Kherson Regional Council, 33 Molodizna st., Kherson, 73000 Ukraine
bismaxmail@gmail.com

Abstract. Research goal of the paper is to study the ecological state of the surface waters using spatio-temporal representation of water quality using a geographic information system (GIS), which will provide interdepartmental information interaction and analytical support for environmental and socio-economic decision making. Mathematical modeling of the ecological state of surface waters according to hydrochemical ingredients was carried out in accordance with the ecological classification. The visual interpretation of multidimensional data, which was obtained using GIS technologies, makes it possible to obtain information on the extent and areas of surface waters pollution and to estimate the level of anthropogenic load on hydroecosystems.

Keywords: GIS technology, modeling process, ecological state, hydrochemical ingredients

1 Introduction

Recently, human society has become increasingly aware of the need to have clean rivers, lakes, underground and coastal waters. That is why one of the priorities of the European Union's activities is water protection.

European water policy is aimed at achieving good water quality and steady ecological state of water bodies. In accordance with the Water Framework Directive 2000/60/EC (Directive 2000/60/EC) [1] it is planned to introduce an integrated approach to the protection of all water bodies – rivers, lakes, coastal water and groundwater; water resource management by basin principle; strengthening transnational cooperation of coastal countries (one river basin – one management plan); the effective use of water resources according to principle – the polluter pays;

large-scale involvement of citizens, interested parties, public organizations; improvement of legislation.

The use of modern methods of the water objects monitoring contributes to new opportunities for cooperation in improving the ecological status of hydroecosystems and visual modeling (graphical representation of the model due to a certain standard set of elements) using GIS technologies in the framework of the international process “Environment for Europe”. This is vital for the realization of one of the advantages of visual modeling – communication [2]. The development of visual interpretation of multidimensional data and GIS technologies is connected, in particular, with the fact that it is difficult for a person with his limited three-dimensional spatial imagination, and in most cases it is impossible, to analyze and give generalized assessments of multidimensional objects. Under conditions of the influence of economic activities of enterprises (industrial, agricultural, energy, communal, transport) on aquatic ecosystems particularly important role of communication between users, analysts, managers, the public, etc.

Ecological indication of the state of hydroecosystems can provide information about the extent and nature of water pollution, the distribution of pollution zones in water bodies, and the possible state of the aquatic ecosystem on a seasonal scale. When assessing the scale of anthropogenic pressure on hydroecosystems, it is necessary to identify adverse processes in the aquatic environment, substantiate chemical criteria for water quality and informative biological criteria, determine critical levels of multifactor water pollution, and develop environmental-economic optimization models for local and transboundary pollution of surface waters.

Providing interdepartmental information interaction between stakeholders (water users, scientists, analysts, ecologists, managers, the public, the media) at a local, regional, state and international level and analytical decision support based on modern methods of spatial analysis, modeling the development of emergency situations and predicting their consequences using GIS tools will allow to calculate and visualize the results of modeling the spread of pollution zones in the aquatic environment, contribute to the improvement of environmental health of river basins, improving water quality, sustainable development in Ukraine on the way to human values in a common European home.

The **purpose** of the paper is demonstration of the use of spatial data analysis technology by means of GIS technologies in ecology in assessing the impact of human activities on the state of surface waters.

2 Related Works

Sustainable use of water resources entails the combined use of surface water monitoring and assessment programs with decision making and management tools. The use of GIS-based interpolation to create a continuous map of the whole area and spatial analysis of water quality in areas where sampling does not exist is relevant. Studies were conducted by Aminu M., Matori A.-N., Yusof K.W., Malakahmad A., Zainol R.B. [3] in a similar direction. They included an assessment of the water quality of the Bertam River (Malaysia), which suffered due to the development of tourism-related activities, and were based on data from seven sampling points. As a result, a conclusion was made about the quality of the water surface using the interpolation technique of geographic information system, and its suitability for recreational activities was also assessed.

An equally important area involving the use of geospatial data is land use. For example, Guo Y. and Liu Y. [4] outlined the problem of landscape degradation and habitat fragmentation, which are caused by overuse of resources, including water resources. ArcGIS overlay and least cost path algorithms were used, taking into account relevant environmental and socioeconomic data in GIS projects. A regional ecological network was built, which will serve as the basis for improving the connectivity of the landscape.

In [5], Kussul N., Shelestov A., Basarab R., Skakun S., Kussul O., Lavreniuk M. emphasize that geospatial data including satellite imagery play an important role, since they can provide regular and objective information. The authors use special techniques associated with the area of geospatial intelligence for the qualitative assessment of changes occurring in space and time. The main idea of the proposed geospatial intelligence approach is the use of supervised neural networks in order to classify multi-temporal optical satellite images with the presence of missing data.

The author of Zhang Y. [6] studied coastline changes in the Modern Yellow River delta in China based on remote sensing and GIS techniques. The impact assessment was made using Landstat-5 satellite map images using distance measure tools developed in ArcGIS. It was concluded that human activities had a strong influence on the natural evolution of the Modern Yellow River delta coast.

The focus was also on identifying the critical prone areas for soil erosion, using the Sarada River basin (India) as an example, in the work of scientists Sundra Kumar P., Vankata Praveen T., Anjanaya Prasad M., Santha Rao P. [7]. The basin has been divided into micro basins for effective estimation and also for precise identification of the areas that are prone to soil erosion. Remote Sensing and Geographic Information Systems tools were used to generate and spatially organize the data that is required for soil erosion modeling.

In recent years, the use of remotely sensed data and Geographic Information System (GIS) applications has been found increasing in a wide range of resources inventory, mapping, analysis, monitoring and environmental management. The remote sensing data and GIS based detailed geomorphological and degraded lands analysis ensure according to Reddy G.P.O., Maji A.K., Srinivas C.V., Velayutham M. [8] better understanding of landform-eroded lands relationship and distribution to assess the status of land degradation, geo-environmental planning and management. Similar study also helps in the areas of natural resource management, environmental planning and management, watershed management and hazards monitoring and mitigation.

As a case study area a group of scientists Trabucchi M., O'Farrell P.J., Notivol E., Comín F.A. [9] used a degraded semi-arid Mediterranean river basin in north east Spain. The paper shows that the quantification and mapping of services are the first step required for both optimizing and targeting of specific local areas for restoration.

A critical issue in mapping ecosystem services is data quality and availability. Mapping involves GIS overlay analysis and geoprocessing to combine input layers from diverse sources to derive the final ecosystem service map. Difficulties encountered with deriving ecosystem service maps relate to the scale, age, and accuracy of the input layers.

In the paper [10] by Chen Z., Pan D., Bai Y., a preliminary assessment of ecosystem health in Zhejiang coastal water zone was made, mainly based on remote sensing data and GIS technique. Its spatial and quantitative evaluation was facilitated by the progress of remote sensing and GIS technique development. The results of this research indicate that the coastal water ecosystem health value in winter is worse than in summer, and the farther from shoreline, the better health condition. As compared with the monitoring results of State Oceanic Administration, the results show the credibility of this work. Therefore, the research proves the applicability of remote sensing data and GIS analysis data as indicators for the coastal water ecosystem health assessment.

3 Modeling Process of Self-Purification of Surface Waters

The ecological state of natural waters largely depends on their ability to self-purification. In the study of pollution and self-purification processes, the following main areas are distinguished:

– establishment of dependence of changes in water quality on the hydrological regime and the estimated characteristics of the flow;
– study of chemical, physicochemical transformations of pollutants in water bodies;
– study of biochemical processes of transformation of pollutants.

Along with hydrological factors, an important role in the process of self-purification belongs to physicochemical and biochemical processes. Chemical processes are closely related to biological ones in natural waters. It is often difficult to tell where one process ends and another begins. The decisive role in this complex belongs to biological processes. However, physicochemical processes will dominate when highly toxic pollutants are present in the water, or unfavorable conditions are created for the vital activity of animals and plant organisms, in which biological processes are reduced to a minimum. So, the self-purification of watercourse or water body depends on many factors: the volume of runoff, the velocity and turbulence of the stream, the chemical composition and temperature of water, the level of water pollution [11].

Aeration of water bodies is also important; it provides the saturation of water with oxygen and increases the intensity of the self-purification process. The supply of oxygen to water increases with increasing flow turbulence and lowering the temperature of the water. Therefore, in water reservoirs, water self-purification occurs slower than in rivers. On hot summer days with high temperatures, the process of self-purification slows down due to lack of oxygen, which dissolves slower in warm waters. The self-purification process also stops in winter, when ice does not allow oxygen to pass into the water [11].

When sewage is discharged into the river, the oxygen content in the water first decreases, and then, as water moves along the stream, the amount of oxygen increases and gradually recovers. However, water must pass a certain segment of the river bed for this. The effect of self-purification may stop if the amount of pollutants will exceed the maximum permissible concentration (MPC). For fishery water bodies, wastewater discharge standards are determined by the value of fish breeds, the conditions of their breeding and feeding. In winter, when the oxygen (O_2) content drops to 6 mg/dm^3, it is prohibited to discharge wastewater into water bodies.

Assessment of the ecological state and the capability of self-purification of surface water is a complex task. The coefficient of self-purification rate (degradation rate) K (hour^{-1}, day^{-1}) characterizes the time required for the decomposition of substances to a certain state, and can be approximately calculated by Streeter H.W. formula [12]:

$$K = \frac{2{,}3}{\tau} \lg \frac{C_0}{C_\tau} = \frac{1}{\tau} \ln \frac{C_0}{C_\tau}, \tag{1}$$

where τ – lag-time of water between the gauge stations, hour, day; C_0 and C_τ – the concentration of the substance, respectively, in the initial and final (after the time τ) gauge stations, mg/dm^3.

If the self-purification coefficient (K) and the lag-time of water (τ) from the upper to the lower gauge station are known, the concentration of the pollutant in the gauge station can be determined in a time that is equal to τ:

$$C_\tau = C_0 \cdot 10^{-\frac{\tau KC}{2{,}3}} = C_0 e^{-\tau KC}. \tag{2}$$

The self-purification coefficient (K), the lag-time of water (τ) and the concentration of the pollutant in the lower gauge station will depend on the water exchange processes in the river, which are formed naturally and anthropogenically.

Recently, the determination of chemical oxygen consumption (COD) is used as a general criterion for reducing the concentration of organic compounds in water. This makes it possible to judge the pollution of water bodies with organic substances.

The German scientist B. Hawk used the differential equation to determine the degree of decrease in the concentration of organic substances at various distances from the places of wastewater discharge [13]:

$$\frac{dI}{d\tau} = -kI, \tag{3}$$

where τ – lag-time of water between the gauge stations, hour, day; I – COD in the water body over time τ, mg/dm^3; k – COD destruction factor, 1/ day.

This equation can be written as:

$$T = T_0 \cdot e^{-k\tau}, \qquad (4)$$

where T_0 – COD value in the water body at the point of complete mixing of water, mg/dm^3.

When the COD is determined in two gauge stations (A; B) at different distances along the river by transforming equation (4), it is possible to determine the value of K, which will characterize the total oxidation rate:

$$K = \frac{2{,}3}{\tau} \lg \frac{T_A}{T_B} \cdot day^{-1}, \qquad (5)$$

where T_A and T_B – the value of COD in gauge stations A and B.

The self-purification capability of surface water (in percent) in a section of a water body can be determined by the equation [14]:

$$C = \frac{C_1 - C_2}{C_1} \cdot 100\%, \qquad (6)$$

where C – the percentage of purification; C_1 – concentration of the substance in the upper (initial) gauge station of the section, mg/dm^3; C_2 – concentration of the substance in the lower (final) gauge station of the section after a certain time, mg/dm^3.

4 Mathematical Model of the Ecological State of the Surface Waters of the Lower Section of the Dnieper River According to the Hydrochemical Ingredients

Spatio-temporal information, which is used for modeling, covers the following components rubricator for the territory of the Lower Section of the Dnieper River:

– geographical and geological description;
– hydrochemical ingredients and water quality assessment methods.

The data of the analytical monitoring of surface waters of the Kherson Water Resources Board for the 2013–2018 was used to assess the ecological state of the Lower Section of the Dnieper River on points of supervisions of water: 1 – the Dnieper River – town Novovorontsovka-Ushkalka, Kakhovka Reservoir (195 km from the mouth), 2 – the Dnieper River – low tail-water of Kakhovka HPS (92 km from the mouth), 3 – the Dnieper River – city Kherson, 1 km upstream the city (40 km from the mouth), 4 – the Dnieper River – village Kizomys, arm of a river Rvach (0 km from the mouth) (fig. 1).

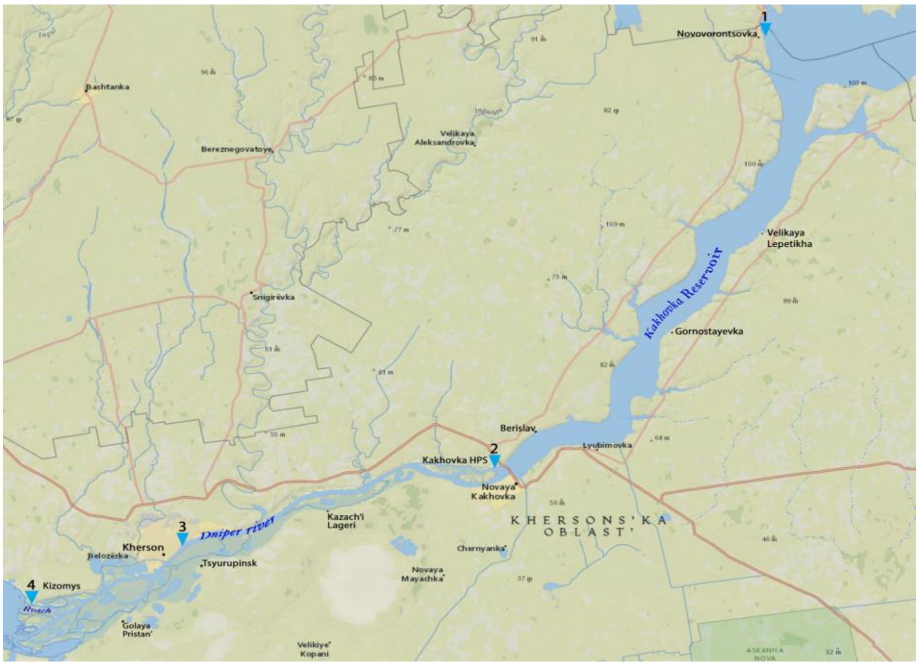

Fig. 1. Scheme of the Lower Section of the Dnieper River

As a result of the research, it was found that over the observation period of 2013–2018 for the territory of the Lower Section of the Dnieper River, there is an excess of COD concentrations according to fishery standards along the length of the river and in time, which indicates water pollution, but does not provide information on the components of pollution. The self-purification ability of surface waters (6), calculated from the observed COD, for 2018 takes negative values ($C \in [-12,7; -3,9]$). This confirms the results of previous research [15] and allows us to conclude that the level of self-regulation and self-purification of the surface waters of the Lower Section of the Dnieper River is low.

Data analysis of analytical control of surface waters by gauge stations of the Lower Section of the Dnieper River for 2013–2018, allowed to identify the excess of the measured values of hydrochemical ingredients relative to the MPC on fisheries standards from 1.3 (COD) to 4.6 (Copper) (fig. 2).

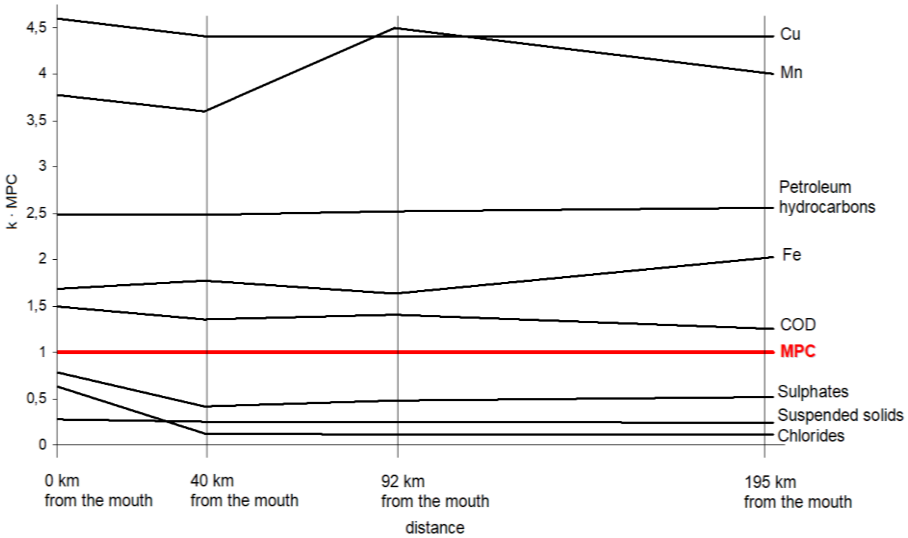

Fig. 2. Excess annual average values (2013–2018) of hydrochemical ingredients relative to MPC of the Lower Section of the Dnieper River

The method of environmental assessment of surface water quality according to the relevant categories [16] allows analyzing observational data, determining the classes and categories of water quality, the state of water bodies, and assessing the conditions for the restoration of water resources using many tables. We propose to express the dependence of the category of water quality on the concentration of hydrochemical ingredients in the form of a regression equation. The following are examples of such a representation of the dependencies of the water quality categories on the values of COD, Suspended solids, Chlorides, Sulphates (fig. 3), Petroleum hydrocarbons, Iron, Copper and Manganese (fig. 4).

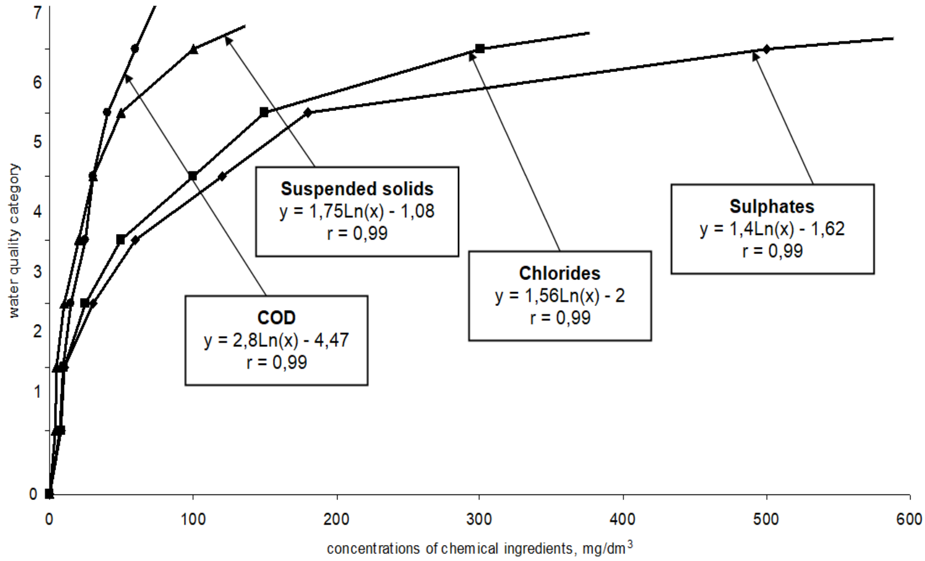

Fig. 3. Dependence of the category of surface water quality on the concentration of hydrochemical ingredients (COD, Suspended solids, Chlorides, Sulphates)

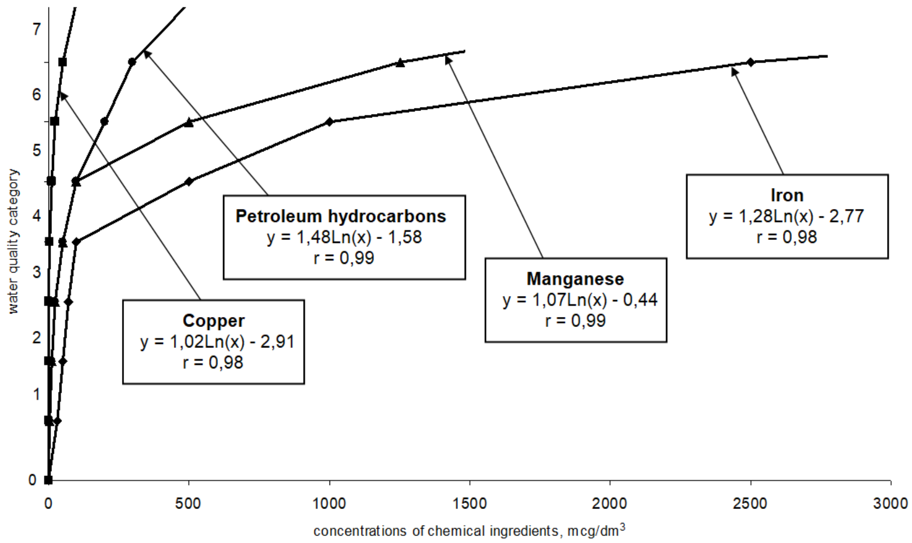

Fig. 4. Dependence of the category of surface water quality on the concentration of hydrochemical ingredients (Cu, Petroleum hydrocarbons, Mn, Fe)

As a result of constructing approximating curves according to the values of the concentrations of hydrochemical ingredients, regression equations are obtained. They are logarithmic dependencies. (fig. 3, 4). The dependency equations are characterized by the values of the correlation coefficients from 0.98 to 0.99, which indicates the presence of close connections between the values of the provided sample. The obtained dependences provide an opportunity to determine the category of surface water quality (vertical axis) based on measured concentrations of the corresponding hydrochemical ingredients (horizontal axis). They can serve as a basis for visualizing the results of modeling the ecological state of surface waters using GIS technologies.

5 Visualization of the Ecological State of the Surface Waters of the Lower Section of the Dnieper River using GIS Technologies

An environmental assessment of the quality of the surface waters of the Lower Section of the Dnieper River was carried out on the basis of the analysis of hydrochemical ingredients for the observation period of 2013–2018 with subsequent calculation and generalization. The results of spatial generalization are presented in the form of maps of the ecological state of surface waters according to the content of water quality indicators.

We presented in out study the possibilities of self-purification of a water body (water quality) in space through a decrease the concentrations of harmful substances through visual changes (color indication).

A software product was developed that made it possible to implement a visual model of the distribution of pollutants between observation places along the length of the river. The program allows, on the basis of the input data, to obtain a gradient coloring of the river bed in a color range that corresponds to a certain category of water quality (table 1).

Table 1. Environmental water quality assessment by ecological classification

Color	Water quality category	Water quality class	Water condition	The extent of water purity
	1	I	excellent	very clean
	2	II	very good	clean
	3		good	sufficient clean
	4	III	acceptable	poorly contaminated
	5		mediocre	moderately contaminated
	6	IV	poor	contaminated
	7	V	very poor	very contaminated

Examples of obtained images are shown for the values of COD, Suspended solids, Chlorides, Sulphates (fig. 5), Petroleum hydrocarbons, Iron, Copper and Manganese (fig. 6).

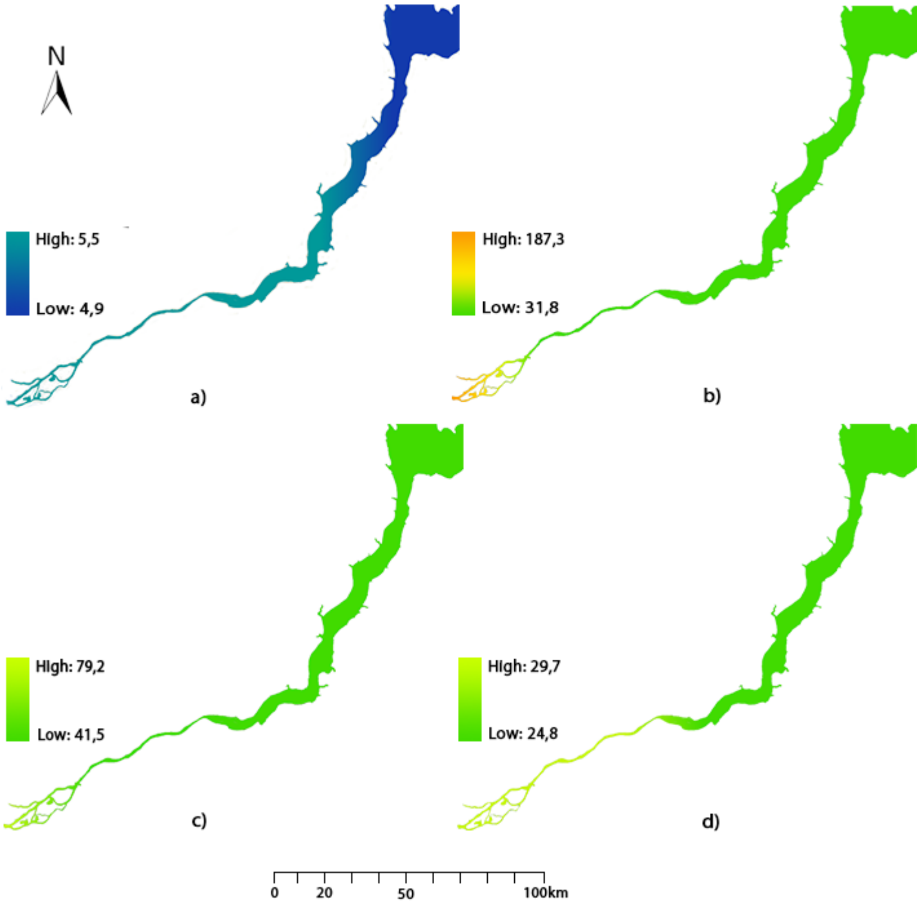

Fig. 5. Ecological state of the surface waters of the Lower Section of the Dnieper River by hydrochemical ingredients, mg/dm^3: a - Suspended solids, b - Chlorides, c - Sulphates, d - COD

The basis for the implementation of the graphical image of the ecological state model was formed by such development tools as HTML, CSS and JavaScript, which allows for close integration with Web 2.0 technology. This gives the possibility of placing software on the Internet and provides free access to it for scientific and educational purposes.

Correspondence of ranges of the category scale and hexadecimal values of the additive RGB color model for visualization of numerical indicators was carried out. The distribution of colors is performed by dividing the color spectrum into seven equal segments in the area from dark blue to red, which corresponds to the minimum and maximum values of the numerical values of the hydrochemical ingredients.

ArcGis cartographic materials were used to form an image of the river bed.

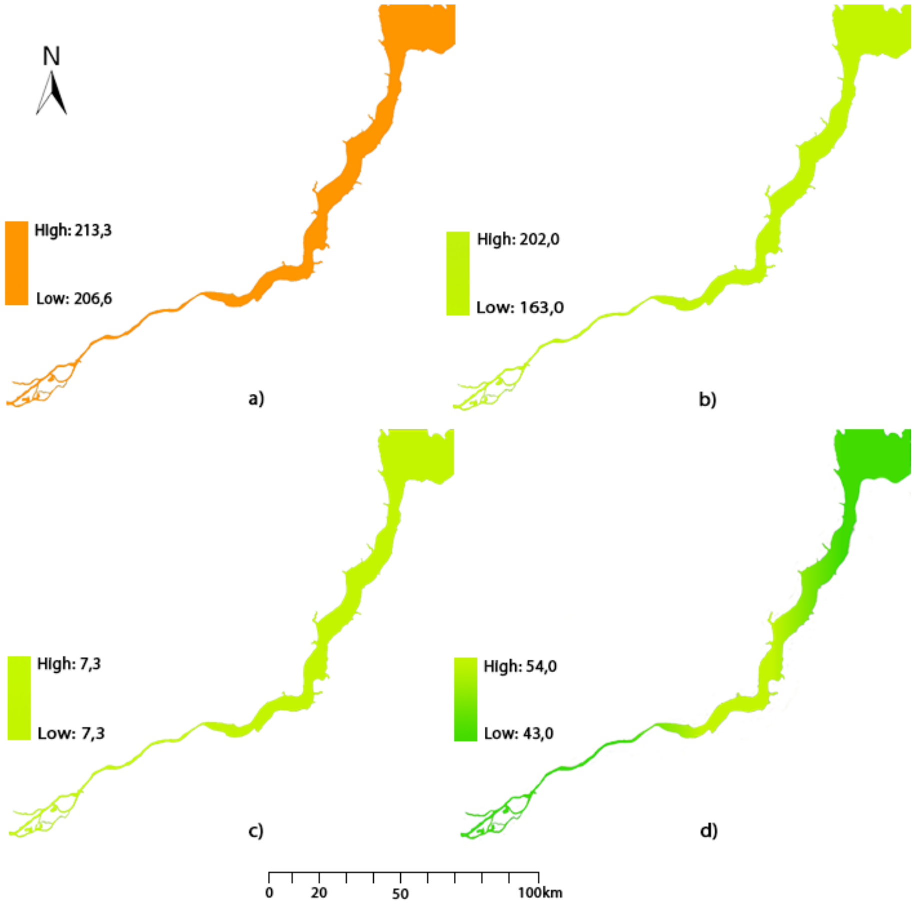

Fig. 6. Ecological state of the surface waters of the Lower Section of the Dnieper River by hydrochemical ingredients, mcg/dm^3: a - Petroleum hydrocarbons, b - Fe, c - Cu, d - Mn

The convenience of use of these technologies consists in the independence of the choice of the operating system to ensure the operability of the software product because any modern browser will allow to successfully use this software.

The obtained maps demonstrate the ecological state of the surface waters of the Lower Section of the Dnieper River, which varies from "excellent" by Suspended solids for the Kakhovka Reservoir (Class I, Category 1, very clean water) (fig. 5, a) to "poor" by Petroleum hydrocarbons for all observation area (Class IV, Category 6, contaminated water) (fig. 6, a).

The unstable ecological state and the change in the water quality of the Lower Section of the Dnieper River are explained by the flow of polluted water from the Ingulets River (between 2 and 3 gauge stations) [17, 18] and stream flow control by the Kakhovka HPS-1 [19, 20].

Low self-purification ability of the surface waters of the Lower Section of the Dnieper River, located on the technogenically loaded area [17-20], indicates that the anthropogenic load on the water body has reached a critical level. It is necessary to provide scientifically based calculations of any type of economic activity [21], carried out in the river basin, to restore the ability of the hydroecosystem to self-regulation and self-purification. Recovery of self-purification processes of the Lower Section of the Dnieper River is possible due to the optimization of the regime of Kakhovka HPS-1 [18, 20] releases and/or building Kakhovka HPS-2 [22]. The activation of the external water exchange will unambiguously increase the intensity of the river ability to cleanse water masses, will improve the water quality in the system of the Lower Section of the Dnieper River and the ecological state of the hydroecosystem.

6 Conclusions and Outlook

The research results presented in this article can be the basis for establishing trends changes in the ecological state of the surface waters of the Lower Section of the Dnieper River in time and space, determining the impact of anthropogenic load on ecosystems of water bodies, estimating changes of water quality, informing the public, solving economic and social issues, related to the rational use of natural resources and ensuring environmental protection.

Visual interpretation of changes in the state of natural systems (color indication of water quality) allows governing bodies (including those without special environmental education) to make quickly decisions on regulating the anthropogenic load on a water body (for example, reduce the volume of wastewater discharges, stop the enterprise, increase releases from Kakhovka reservoir, etc.). In addition, the digital indication of water quality is presented not only in quantitative terms, but also in qualitative assessment.

Perspectives for further research can be represented by the use of GIS technologies for the spatio-temporal representation of the ecological state of the Lower Section of the Dnieper River on the integrated index and ecological reliability of the water body.

References

1. Directive, EU Water Framework. "60/EC Definitions of Main Terms." (2006).
2. Mokin, V. B., Kryzhanovsky, E. M. Geoinformatic Systems in Ecology. Vinnitsa: VNTU. (2014).
3. Aminu, M., Matori, A.-N., Yusof, K. W., Malakahmad, A., Zainol, R. B. A GIS-based water quality model for sustainable tourism planning of Bertam River in Cameron Highlands, Malaysia. Environmental Earth Sciences, 73(10), 6525–6537. (2014). doi:10.1007/s12665-014-3873-6
4. Guo, Y., Liu, Y. Connecting regional landscapes by ecological networks in the Greater Pearl River Delta. Landscape and Ecological Engineering, 13(2), 265–278. (2016). doi:10.1007/s11355-016-0318-2
5. Kussul, N., Shelestov, A., Basarab, R., Skakun, S., Kussul, O., Lavrenyuk, M. Geospatial Intelligence and Data Fusion Techniques for Sustainable Development Problems. ICTERI, 1356, 196-203. (2015).

6. Zhang, Y. Coastal environmental monitoring using remotely sensed data and GIS techniques in the Modern Yellow River delta, China. Environmental Monitoring and Assessment, 179(1-4), 15–29. (2010). doi:10.1007/s10661-010-1716-9
7. Sundara Kumar, P., Venkata Praveen, T., Anjanaya Prasad, M., Santha Rao, P. Identification of Critical Erosion Prone Areas and Computation of Sediment Yield Using Remote Sensing and GIS: A Case Study on Sarada River Basin. Journal of The Institution of Engineers (India): Series A. (2018). doi:10.1007/s40030-018-0293-8
8. Reddy, G. P. O., Maji, A. K., Srinivas, C. V., Velayutham, M. Geomorphological analysis for inventory of degraded lands in a river basin of basaltic terrain using remote sensing and GIS. Journal of the Indian Society of Remote Sensing, 30(1-2), 15–31. (2002). doi:10.1007/bf02989973
9. Trabucchi, M., O'Farrell, P. J., Notivol, E., Comín, F. A. Mapping Ecological Processes and Ecosystem Services for Prioritizing Restoration Efforts in a Semi-arid Mediterranean River Basin. Environmental Management, 53(6), 1132–1145. (2014). doi:10.1007/s00267-014-0264-4
10. Chen, Z., Pan, D., Bai, Y. Study of coastal water zone ecosystem health in Zhejiang Province based on remote sensing data and GIS. Acta Oceanologica Sinica, 29(5), 27–34. (2010). doi:10.1007/s13131-010-0060-9
11. Sheludchenko, B.A. Engineering Ecology. Ch. 2. Hydrosphere: (Textbook), B. A. Sheludchenko, V. V. Doroshenko, V. I. Kotkov. Zhytomyr: Volyn (2001).
12. Streeter, H. W., Phelps, E. B. A Study of the Pollution and Natural Purification of the Ohio River. US Department of Health, Education, & Welfare. (1958).
13. Sinelnikov, V. E. Problems of pure water. Moscow. Znanije. (1978).
14. Vladimirov, A. M., Orlov, V. G. Protection and monitoring of surface waters of the land. (2009).
15. Shakhman, I. A., Bystriantseva, A. N. Assessment of ecological state and ecological reliability of the Lower section of the Dnieper River 18th International Multidisciplinary scientific Geoconference SGEM, Albena, 2.-8.07. 2018. Vol-18. 113-119. (2018).
16. Gritsenko, A. V., Vasenko, O. G., Vernichenko, G. A. et al Methodology of ecological assessment of surface water quality by appropriate categories. Kh. UkrNIEP. (2012).
17. Lykhovyd, P. V., Kozlenko, Ye. V. Assessment and forecast of water quality in the River Ingulets irrigation system. Ukrainian Journal of Ecology 8.1: 350-355 (2018).
18. Shakhman, I. A., Bystriantseva, A. N. Assessment of Ecological State and Ecological Reliability of the Lower Section of the Ingulets River. Hydrobiological Journal 53.5 (2017).
19. Timchenko, V., Oksiyuk, O. Ecosystem condition and water quality control at impounded sections of rivers by the regulated hydrological regime. International Journal of Ecohydrology and Hydrobiology 1.02 (2002).
20. Timchenko, V. M., Korzhov, Y. I., Guliayeva, O. A., Batog, S. V. Dynamics of Environmentally Significant Elements of Hydrological Regime of the Lower Dnieper Section. Hydrobiological Journal, 51(6). (2015).
21. Kobets, V., Bystriantseva, A., Shakhman, I. GIS Based Model of Quotas Regulation and its Impact on the Extraction of Ecosystems' Natural Resources and Social Welfare. ICTERI, 2105, 151-166. (2018).
22. Execution of design work, development of the section "Assessment of the environmental impact". Feasibility study. Final report. 1606-69-Vol. 7. (2015).