THE ECOLOGICAL ASSESSMENT OF SMALL RIVERS IN UKRAINE UNDER CONDITIONS OF INTENSIVE WAR IMPACT

IRYNA PATSEVA*, VITALINA LUKIANOVA**, YEVHENIIA ANPILOVA[1]***, LIUDMYLA MOHELNYTSKA****, OLENA GERASIMCHUK*****

Key-words: ecological assessment, anthropogenic impact, water pollution index (WWI).

Abstract. Aquatic ecosystems are perpetually exposed to anthropogenic sources of pollution, wherein the quality of subterranean and surface waters undergoes influence from both natural and anthropogenic processes. This interaction results in environmental predicaments and, occasionally, environmental crises. Small rivers, in particular, bear a pronounced impact from human interventions on the environment. The investigation undertaken by the researchers commenced in 2021 with the primary objective of scrutinizing the ecological condition of the Irsha River. Regrettably, due to the military aggression of the Russian Federation, the regions through which the river courses were temporarily occupied, subject ting it to considerable anthropogenic disturbances. Specifically, two bridges spanning the Irsha River in the Malyn area were demolished, and military operations transpired along the riverbanks, leading to the accumulation of damaged military equipment. Consequently, it was deemed imperative during the course of our study to conduct an analysis of the natural water in the Irsha River subsequent to the military activities. The outcomes of a comprehensive assessment of surface water quality, employing a graphical method, revealed that, during the period of 2021–2022, the river waters within the Irsha River exhibited an overall failure to meet quality standards in both monitoring locations. Elevated values of Maximum Permissible Concentration (MPC) exceeding the norm were noted for the Chemical Oxygen Demand (COD) indicator, the dissolved oxygen indicator, as well as the general iron and iron of permanganate oxidizability parameters in both samples. The highest degree of pollution was discerned in the Malyn Reservoir, whereas the Irsha Reservoir manifested comparatively lower pollution levels in the aquatic environment.

1. INTRODUCTION

The use of small river ecosystems in modern ecological conditions is extensive and destructive for them (Kunakh *et al*., 2023; Zhukov *et al*., 2018). This is manifested in the excessive anthropogenic use of river basins (deforestation, the ploughing of more than 80% of the territory, residential, communal and industrial construction, etc.), the increase in the volume of polluted economic, communal and industrial wastewater entering the river waters, the destruction of the river bed due to the intensification of water and erosion processes (Kotsiuba *et al*., 2022; Fryirs, 2017), the flowing of drainage water from unauthorized landfills into water bodies (Kotsiuba *et al*., 2023). It is small rivers that form the hydrochemical composition and water quality of the medium and large rivers of Ukraine. Due to the small catchment areas, they are the most vulnerable to destructive anthropogenic influence, so they

* Associate Professor, Zhytomyr Polytechnic State University, Chudnivska str., 103, Zhytomyr, 10005, Ukraine, chaszmin30@gmail.com.

** Senior Researcher, State Institution “Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine”, Academician Palladin Avenue, 34a, Kyiv, 03142, Ukraine, w.carpediem1@gmail.com.

*** Senior Researcher, UFZ-Helmholtz Centre for Environmental Research, Permoserstr., 15, 04318, Leipzig, Germany, Institute of Telecommunications and Global Information Space of the National Academy of Sciences of Ukraine, Chokolovsky Blvd., 13, 03186, Kyiv, Ukraine, yevheniia.anpilova@ufz.de.

**** Associate Professor, Zhytomyr Polytechnic State University, Chudnivska str., 103, Zhytomyr, 10005, Ukraine, mogeln_l@ukr.net.

***** Associate Professor, Zhytomyr Polytechnic State University, Chudnivska str., 103, Zhytomyr, 10005, Ukraine, kgt_gol@ztu.edu.ua.

[1] Corresponding author

require a constant monitoring of water quality. And, in cases of significant pollution, they require expensive methods of water purification (Tarasevich *et al*., 2008; Kotsiuba *et al*., 2019).

Beyond regional boundaries, today's global studies (such as Abbott *et al*., 2019; Abdar *et al*., 2021; Allen and Holling, 2010; Aravinthasamy *et al*., 2020; Batabyal, 2018; Chin *et al*., 2013; Downs *et al*., 2013; Florsheim *et al*., 2013; Francis, 2011; Graf, 2001; Irvan *et al*., 2021; Stojković *et al.*, 2018; Kenniche *et al*., 2022; Kılıç, 2018; van Vliet, M. T. H., 2023; Varadharajan *et al*., 2022; Urooj *et al*., 2019) contribute to a broader understanding of water quality issues. They provide a nuanced understanding of water quality in different geographical contexts, highlighting the need for integrated approaches to address regional challenges, anthropogenic impacts, climate change and the role of advanced methodologies in water quality assessment.

The present-day state water quality monitoring system in Ukraine is focused on monitoring the hydrochemical composition of water in large and medium-sized rivers, while small rivers are practically not included in the monitoring network. The lack of reliable data on small river water quality makes it impossible to carry out a comprehensive assessment of the ecological state of their basins and to develop measures for its optimization. Based on the above mentioned, it becomes relevant to study the chemical composition of small river waters with a comprehensive and in-depth analysis of the direction of hydrochemical processes occurring in them, as a result of the combined effect of natural and anthropogenic factors on an open hydrochemical system.

The main task of this work is to carry out a comprehensive ecological assessment of the Irsha River surface water quality based on the analytical method.

2. STUDY AREA CHARACTERISTICS

The following tasks are completed to achieve the goal of the study:

1. The Irsha River basin is characterized within the study area;
2. A comprehensive assessment of the Irsha River surface water quality is performed based on the graphical method;
3. The level of river pollution is assessed according to the modified index.

The relevance of the topic is determined not only by the importance of using the Irsha River water for various purposes: a source of drinking water supply, energy, as a recreational facility, for irrigation, fishing, etc. The results of this work can be used to assess the impact of the Russian Federation's aggression on the environment.

The main polluters of the Irsha River in the pre-war period were housing and communal enterprises (4 enterprises). Their share is 90% of the polluted return waters. Complexes of sewage treatment facilities of communal enterprises are outdated and work inefficiently, so they need to be reconstructed with the introduction of modern wastewater treatment technologies.

3. DATA AND METHODS

The data of hydrochemical observations from two control bodies of the river network of Zhytomyr region (Ukraine) were used as initial information for the study of the Irsha River qualitative state. The water quality monitoring of the Irsha River was carried out at the approved state water quality monitoring point 93 km from the mouth (Fig. 1), Irsha Reservoir, in the drinking water intake of Nova Borova village and at the point which is 31 km from the mouth in the drinking water intake of Malyn (Fig. 2).

Various methods are used to study the surface water quality and level of pollution (APHA, 1985; Archfield *et al*., 2015; Arya *et al*., 2021; Diamantin *et al*., 2018; Comber *et al*., 2022; Kikuchi *et al*., 2022; Petrie *et al*., 2015; Karunanidhi *et al*., 2021; Muangthong and Shrestha, 2015; Nair *et al*., 2021; Solovey *et al*., 2021; Stackpoole *et al*., 2019; Sprague *et al*., 2017; Taylor *et al*., 2016), in particular the analytical-synthetic method, the geo-informational (cartographic modelling) method, and the analysis of information sources. To determine the Irsha River water quality and the level of its pollution, a graphical method of comprehensive assessment of surface water quality and a modified pollution index were applied in our work.

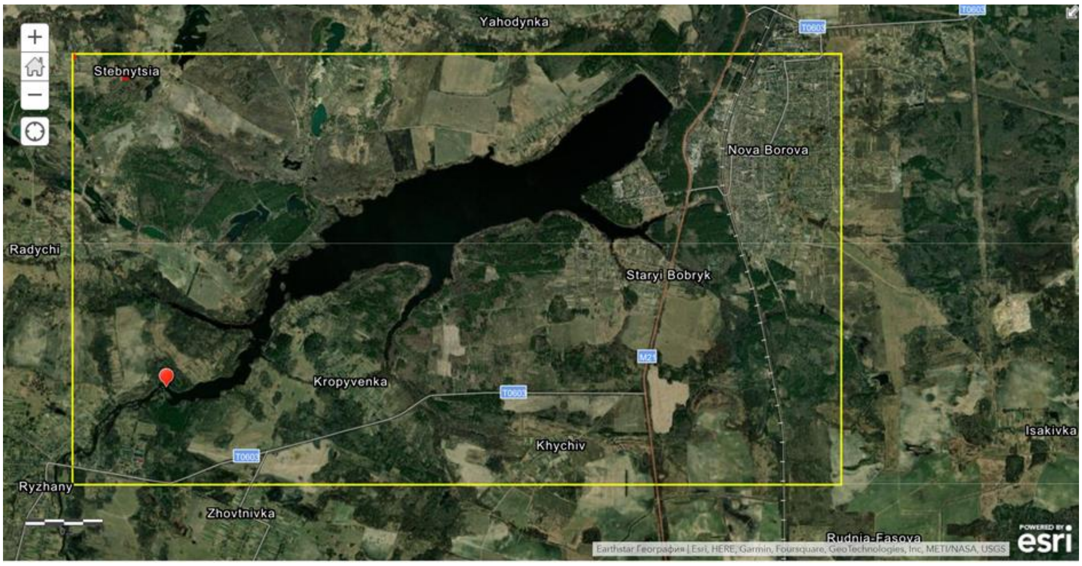

Fig. 1 – The object of the study: Irsha River, Nova Borova district.
Source: https://livingatlas.arcgis.com.

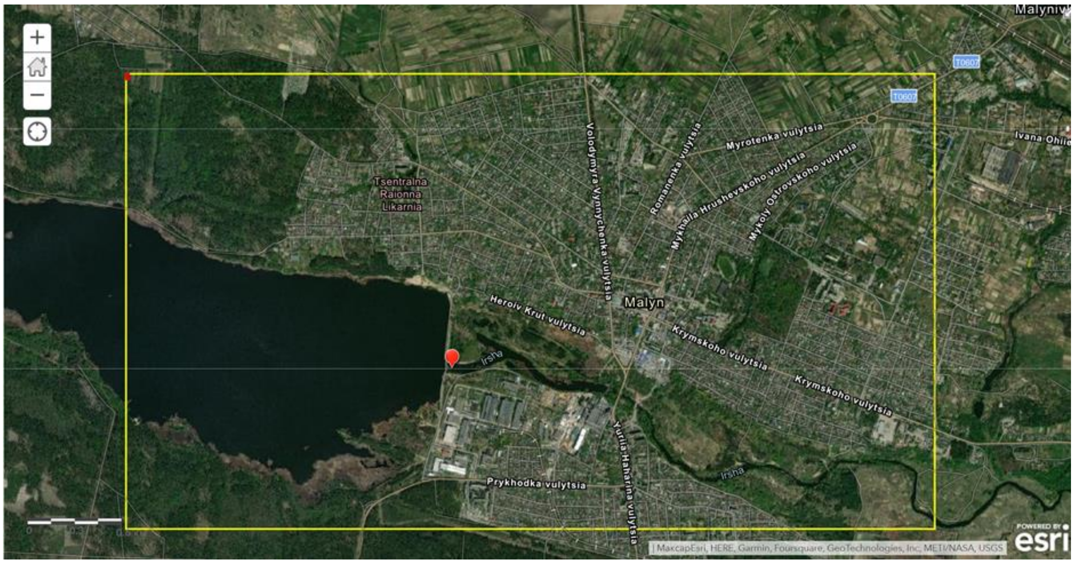

Fig. 2 – The object of the study: Irsha River, Malyn district. Source: https://livingatlas.arcgis.com.

The graphical method regarding the complex assessment of surface water quality is based on the compilation of a graphical model of surface water quality, which is a circular diagram with scale-radii corresponding to a certain hydrochemical indicator. The value of each radius division is equal to the maximum concentration value of the indicator that determines the suitability of water for a certain type of water use, that is, the maximum permissible concentrations (MPC) of pollutants in the water body. The graphical model consists of two diagrams. One is a circle with a unit radius, and the second is a polygon with the number of vertices equal to the number of hydrochemical indicators. The border of the circle is the border of the ecological optimum, i.e., the ecological state of the water body when the content of all pollutants does not exceed the MPC (Muangthong and Shrestha, 2015).

The assessment of water quality according to the pollution index (PI) is carried out according to a limited number of indicators. The average arithmetic value of chemical analyses results for each of the indicators is determined. The found average arithmetic value of each of the indicators is compared with their MPC. The pollution Index (PI) is estimated by equation 1:

$$PI = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{MPC_i}$$

where MPC_i – maximum permissible concentration (value) of the i-th indicator; C_i is the actual concentration (value) of the i-th indicator; n is the number of indicators.

This method of water quality assessment consists in calculating the water pollution index based on hydrochemical parameters, and then, based on the values of the calculated PI, the water under investigation is assigned to the appropriate quality class. Based on the results of the assessment, the following water quality classes are distinguished (Kolisnyk, *et al*., 2019; Ali *et al*., 2021): I – very clean (PI < 0,3); II – clean (0,3 < PI < 1); III – moderately polluted (1 < PI < 2,5); polluted (2,5 < PI < 4); IV – dirty (4 < PI < 6); V – very dirty (6 < PI < 10); VI – extremely dirty (PI > 10).

The study uses a modified method of calculating the PI, when some of the indicators are constant, and the others are taken as the indicators with the greatest relationship to the MPC. This allows a more complete use of the available hydrochemical information (Kolisnyk *et al*., 2019).

4. RESULTS

The assessment of surface water quality in the Irsha River was performed on the basis of the graphical method for 2021-2022 in two control bodies: the Irsha River, the left tributary of the Teteriv River, 93 km from the mouth, Irsha Reservoir, the drinking water intake of Nova Borova village; Irsha river, 31 km from the mouth, Malyn reservoir, Malyn drinking water intake. Figures 3, 4 present the results for 2021.

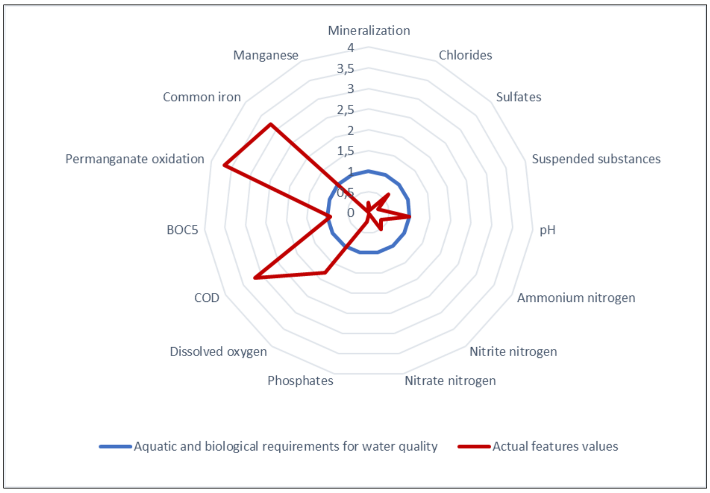

Fig. 3 – Concentrations of substances in control water bodies (Irshansk Reservoir, body 1) for the year 2021, in multiplicity units of the corresponding MPC.

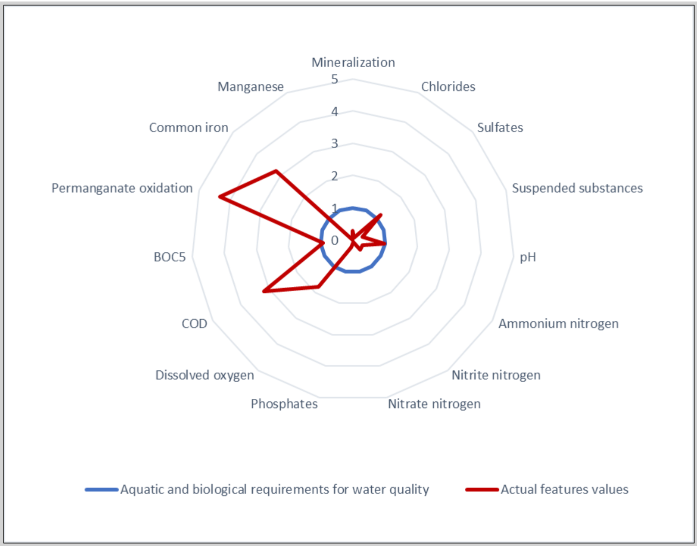

Fig. 4 – Concentrations of substances in control water bodies (Malyn Reservoir, body 2) for the year 2021, in multiplicity units of the corresponding MPC.

The quality of river waters in the region was found to be satisfactory in 2021. All quality indicators, including mineralization, chlorides, suspended matter, pH, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phosphates, dissolved oxygen, BOD5 and manganese, met the requirements for river water quality.

The MPC multiplicity indicator in excess for sulphates during the entire period varied between 1.15 MPC and 1.3 MPC, as the highest value of the multiplicity indicator was observed in 2021 in the Malyn reservoir. According to the COD indicator (3.18 MPC-3.44 MPC), the highest MPC exceedance of 3.44 times was noted in the water of the same body. The Irsha River water quality in both bodies is unsatisfactory in terms of iron content; the highest value of the MPC multiplicity indicator in excess for iron was noted in both bodies of the Irsha River water (3.2 MPC).

According to the water permanganate oxidizability indicator, the greatest exceedance of the MPC, by 5.3 times, was observed in 2021 in the Irshansk Reservoir. This is the maximum excess among all hydrochemical indicators.

Analysing the graphs displaying the results of river water quality assessment in 2021, it should be noted that:

- in reservoir 1 (Irshansk Reservoir), the water is least polluted by manganese (0.006 MPC) and chlorides (0.07 MPC), and the most significant is permanganate oxidizability (3.7 MPC);
- in reservoir 2 (Malyn Reservoir) there is a high level of pollution according to the COD indicator (3.18 MPC) and total iron (3.2 MPC), and the highest value of the MPC exceeding the frequency indicator is acquired by permanganate oxidation (4.3 MPC). Compared to the previous year (2018), the concentration of sulphates (1.12 MPC) in this body decreased, in 2019, to a level below the norm (0.66 MPC).

Table 1 displays the results of a comprehensive assessment of surface water quality using the graphical method. The data clearly shows high values of the maximum permissible concentration (MPC) for COD, dissolved oxygen, general iron, and iron of permanganate oxidizability in both bodies during 2021–2022. In general, the river water in the two observation areas of the Irsha River does not meet the quality requirements.

Table 1

The results of the assessment of the river water pollution level according to the modified pollution index

Bodies	2021–2022		
	Pollution index	Class	Feature
Irsha river, 93 km from the mouth, Irshansk Reservoir, drinking water intake, Nova Borova village	1,074	III	moderately polluted
Irsha river, 31 km from the mouth, Malyn Reservoir, drinking water intake, Malyn	1,153	III	moderately polluted

The pollution index calculation by year in different bodies for the 2021–2022 period showed a decrease in water pollution in both bodies. Thus, a 12% reduction in pollution was observed in the Irshansk Reservoir, and pollution was reduced by 5.5% in the Malyn Reservoir.

5. CONCLUSIONS

A comprehensive assessment of surface water quality using graphical methods revealed that in 2021–2022 both bodies of water had high levels of indicators that exceeded the maximum permissible concentration of COD, dissolved oxygen, general iron, and iron of permanganate oxidizability. Therefore, one may conclude that the water in the Irsha River at the two observation sites does not meet quality requirements.

The Malyn reservoir (Irsha river, 31 km) has been identified as having the highest pollution level based on the revised pollution index. It is worth noting that both bodies of water in the Irsha River are classified as 'moderately polluted' and belong to class III of water quality, which indicates a significant anthropogenic impact. This impact is close to the limit of ecosystem sustainability.

To protect the environment and make rational use of natural resources, it is essential to implement the measures outlined in state and regional target programs. These measures will help to reduce the anthropogenic load and improve the condition of surface water bodies, especially in the Irsha River where pollution levels are currently high.

REFERENCES

Abbott, B. W., Bishop, K., Zarnetske, J. P., Hannah, D. M., Frei, R. J., Minaudo, C., Chapin, F. S., Krause, S., Conner, L., Ellison, D., Godsey, S. E., Plont, S., Marçais, J., Kolbe, T., Huebner, A., Hampton, T., Gu, S., Buhman, M., Sayedi, S. S., Pinay, G. (2019), *A water cycle for the Anthropocene*. Hydrological Processes, **33**(*23*), pp. 3046–3052. https://doi.org/ 10.1002/hyp.13544.

Abdar, M., Pourpanah, F., Hussain, S., Rezazadegan, D., Liu, L., Ghavamzadeh, M., Fieguth, P., Cao, X., Khosravi, A., Acharya, U. R., Makarenkov, V., Nahavandi, S. (2021), *A review of uncertainty quantification in deep learning: Techniques, applications and challenges.* Information Fusion, **76**, pp. 243–297. https://doi.org/10.1016/ j.inffus.2021.05.008.

Allen, Craig R., Holling, C.S. (2010), Novelty, adaptive capacity and resilience. Ecology and Society, **15**(3), 24.

Ali, S. Y., Sunar, S., Saha, P., Mukherjee, P., Saha, S., Dutta, S. (2021), *Drinking water quality assessment of river Ganga in West Bengal, India through integrated statistical and GIS techniques. Water Science and Technology: A Journal of the International Association on Water Pollution Research,* **84**(*10–11*), pp. 2997–3017. https://doi.org/10.2166/ wst.2021.293.

APHA (1985), *Standard Method for the Examination of Water and Wastewater*. 16th Edition, American Public Health Association, Washington DC.

Aravinthasamy, P., Karunanidhi, D., Subramani, T., Srinivasamoorthy, K., Anand, B. (2020), *Geochemical evaluation of fluoride contamination in groundwater from Shanmuganadhi River basin, South India: implication on human health*. *Environmental Geochemistry and Health*, **42**(*7*), pp. 1937–1963. https://doi.org/10.1007/s10653-019-00452-x.

Archfield, S. A., Clark, M., Arheimer, B., Hay, L. E., McMillan, H., Kiang, J. E., Seibert, J., Hakala, K., Bock, A., Wagener, T., Farmer, W. H., Andréassian, V., Attinger, S., Viglione, A., Knight, R., Markstrom, S., Over, T. (2015), *Accelerating* *advances in continental domain hydrologic modeling*. Water Resources Research, **51**(*12*), pp. 10078–10091. https://doi.org/10.1002/2015WR017498.

Arya, S., Subramani, T., Vennila, G., Karunanidhi, D. (2021), *Health risks associated with fluoride intake from rural drinking water supply and inverse mass balance modeling to decipher hydrogeochemical processes in Vattamalaikarai River basin, South India*. *Environmental Geochemistry and Health*, **43**(*2*), pp. 705–716. https://doi.org/10.1007/s10653-019-00489-y.

Batabyal, A.K. (2018), *Hydrogeochemistry and quality of groundwater in a part of Damodar Valley, Eastern India: an integrated geochemical and statistical approach.* Stochastic Environmental Research and Risk Assessment, **32**, pp. 2351–2368. https://doi.org/10.1007/s00477-018-1552-y.

Chin, A, O'Dowd A.P., Gregory, K.J. (2013), *Urbanization and river channels*. In *Treatise on Geomorphology*, L Schroder, E Wohl, (eds). Academic Press, San Diego, CA; vol. **9**, pp. 809–827.

Comber, S.D.W., Gardner, M.J., Ansell, L., Ellor, B. (2022), *Assessing the impact of wastewater treatment works effluent on downstream water quality*, Science of The Total Environment. Vol. **845**, 157284. https://doi.org/10.1016/ j.scitotenv.2022.157284.

Diamantin, E., Lutz, S., Mallucci, S., Majone, B., Merz, R., Bellin, A. (2018), *Driver detection of water quality trends in three large European river basins.* Science of The Total Environment, **612,** pp. 49–62. doi: 10.1016/ J.SCITOTENV.2017.08.172.

Downs, P.W., Dusterhoff, S.R., Sears, W.A. (2013), *Reach-scale channel sensitivity to multiple human activities and natural events: Lower Santa Clara River, California, USA.* Geomorphology, **189**, pp. 121–134.

Florsheim, J.L., Chin, A., Gaffney K., Slota, D. (2013*), Thresholds of stability in incised "Anthropocene" landscapes*. Anthropocene, **2**, pp. 27–41.

Francis, R. A. (2011), *The Impacts of Modern Warfare on Freshwater Ecosystems.* Environmental Management, **48**(*5*), 985–999 doi: 10.1007/S00267-011-9746-9.

Fryirs, A. K., (2017), *River sensitivity: a lost foundation concept in fluvial geomorphology*. *Earth Surface Processes and Landforms,* **42**(*1*), pp. 55–70. https://doi.org/10.1002/esp.3940.

Graham, D., Bierkens, M., van Vliet, M. (2023), *Water quality responses under droughts and heatwaves in river basins worldwide.* EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-4295. https://doi.org/ 10.5194/egusphere-egu23-4295.

Graf, W.L. (2001), *Damage control: restoring the physical integrity of America's rivers.* Annals of the Association of American Geographers, **91**, pp. 1–27.

Irvan, Y, Rajagukguk., H, Wahyuningsih, Y, Nabilah (2021), *The effect of industrial waste on the water quality of Padang River in the industrial area of Tebing Tinggi*. IOP Conference Series: Materials Science and Engineering, 1122, 3rd TALENTA Conference on Engineering Science and Technology (TALENTA CEST 2020) 28th September 2020, Medan, Indonesia. doi: 10.1088/1757-899X/1122/1/012072.

Stojković Piperac, M., Milošević, D., Petrović, A., Simić, V. (2018), *The best data design for applying the taxonomic distinctness index in lotic systems: A case study of the Southern Morava River basin.* Science of The Total Environment, **610–611**, pp. 1281–1287. https://doi.org/10.1016/j.scitotenv.2017.08.093.

Karunanidhi, D., Aravinthasamy, P., Subramani, T., Muthusankar, G. (2021), *Revealing drinking water quality issues and possible health risks based on water quality index (WQI) method in the Shanmuganadhi River basin of South India*. *Environmental Geochemistry and Health,* **43**(*2*), pp. 931–948. https://doi.org/10.1007/s10653-020-00613-3.

Kenniche, S., Bekkoussa, B., M'nassri, S., Teffahi, M., Taupin, J-d., Patris, N., Zaagane, M., Majdoub, R. (2022), *Hydrochemical characterization, physicochemical, and bacteriological quality of groundwater in Sidi Kada Mountains, northwest of Algeria.* Arabian Journal of Geosciences, **15**, pp. 1061. https://doi.org/10.1007/s12517-022-10298-w.

Kikuchi, T., Anzai, T., Ouchi, T., Okamoto, K., Terajima, Y. (2022), *Assessing the impact of watershed characteristics and management on nutrient concentrations in tropical rivers using a machine learning method.* Environmental Pollution, **316**(*1*). doi: 10.1016/j.envpol.2022.120599.

Kılıç, E. (2018), *Impact of Syrian Civil War on Water Quality of Turkish Part of Orontes River.* Pollution, **4**(*3*), pp. 503–513. https://doi.org/10.22059/poll.2018.250998.382.

Kolisnyk, A., Romanchuk, M., Volovchuk, N. (2019), *Assessment of the quality and level of pollution of river water within Zhytomyr region on the basis of the graphical method and the modified index / Otsinka yakosti ta rivnya zabrudnenosti richkovikh vod u mezhakh Zhitomirskoji oblasti na osnovi grafichnogo metodu ta modifikovanogo indeksu*. *Ecological safety,* **2**(*28*), pp. 38–43.

Kotsiuba, I., Herasymchuk, O., Shamrai, V., Lukianova, V., Anpilova, Y., Rybak, O., Lefter, I. (2023), *A Strategic Analysis of the Prerequisites for the Implementation of Waste Management at the Regional Level*. *Ecological Engineering & Environmental Technology,* **24**(*1*), pp. 55–66. https://doi.org/10.12912/27197050/154918.

Kotsiuba, I., Lukianova, V., Anpilova, Y., Yelnikova, T., Herasymchuk, O., Spasichenko, O. (2022), *The Features of Eutrophication Processes in the Water of Uzh River*. *Ecological Engineering & Environmental Technology,* **23**(*2*), pp. 9–15. https://doi.org/10.12912/27197050/145613.

Kotsiuba, I., Skyba, G., Skuratovskaya, I.A., Lyko, S. (2019), *Ecological Monitoring of Small Water Systems: Algorithm, Software Package, The Results Of Application To The Uzh River Basin (Ukraine)*. *Methods and Objects of Chemical Analysis,* **14**, pp. 200–207. DOI:10.17721/moca.2019.200-207.

Kunakh, O., Zhukova, Y., Yakovenko, V., Zhukov, O. (2023), *The role of soil and plant cover as drivers of soil macrofauna of the Dnipro River floodplain ecosystems*. *Folia Oecologica,* **50**(*1*), pp. 16–43. https://doi.org/10.2478/foecol-2023-0002.

Muangthong, S., Shrestha, S. (2015), *Assessment of surface water quality using multivariate statistical techniques: case study of the Nampong River and Songkhram River, Thailand*. *Environmental Monitoring and Assessment,* **187**, 548. doi: 10.1007/s10661-015-4774-1.

Nair, J. P., Vijaya, M. S. (2021), *Predictive Models for River Water Quality using Machine Learning and Big Data Techniques – A Survey, International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, Coimbatore, India, pp. 1747–1753. doi: 10.1109/ICAIS50930.2021.9395832.

Petrie, B., Barden, R., Kasprzyk-Hordern. B. (2015), *A review on emerging contaminants in wastewaters and the environment: current knowledge, understudied areas and recommendations for future monitoring.* Water Research, **72**, pp. 3–27. doi: 10.1016/J.WATRES.2014.08.053.

Solovey, T., Wojewódka-Przybył, M., Rafał Janica, R. (2021), *Hydrochemical indicators of water source and contamination in fen peatlands of varying hydrogeomorphic settings in northern and central Poland.* Ecological Indicators, ***129.*** https://doi.org/10.1016/j.ecolind.2021.107944

Stackpoole, S.M., Stets, E. G., Sprague, L. A. (2019), *Variable impacts of contemporary versus legacy agricultural phosphorus on US river water quality.* Proceedings of the National Academy of Sciences of the United States of America, **116**(*41*), pp. 20562–20567. doi: 10.1073/PNAS.1903226116.

Sprague, L. A., Oelsner, G. P., Argue, D. M. (2017), *Challenges with secondary use of multi-source water-quality data in the United States*. *Water Res.* **110**, pp. 252–261. https://doi.org/10.1016/j.watres.2016.12.024.

Tarasevich, Y., Bondarenko, S., Polyakov, V., Zhukova, A., Ivanova, Z., Luk'yanova, V., Malysh G. (2008), *The study of the structural, sorption, and electrochemical properties of a natural composite shungite*. *Colloid Journal*, **70**(*3*), pp. 349–355. https://doi.org/10.1134/S1061933X08030137.

Taylor, S. D., He. Y., Hiscock, K. M. (2016), *Modelling the impacts of agricultural management practices on river water quality in Eastern England*. Journal of Environmental Management, **180**, pp. 147–163. doi: 10.1016/J.JENVMAN.2016.05.002.

Zhukov, O., Kunah, O., Dubinina, Y., Novikova, V. (2018), *The role of edaphic, vegetational, and spatial factors in structuring soil animal communities in a floodplain forest of the Dnipro River*. *Folia Oecologica,* **45**(*1*), pp. 8–23. https://doi.org/10.2478/foecol-2018-0002.

van Vliet, M. T. H. (2023), *River water quality under climate change and extremes: a synthesis of impacts for river basins globally (Invited)*, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr. 2023, EGU23-2361. https://doi.org/10.5194/egusphere-egu23-2361.

Varadharajan, C., Appling, A. P., Arora, B., Christianson, D. S., Hendrix, V. C., Kumar, V., Lima, A. R., Müller, J., Oliver, S., Ombadi, M., Perciano, T., Sadler, J. M., Weierbach, H., Willard, J. D., Xu, Z., & Zwart, J. (2022), *Can machine learning accelerate process understanding and decision-relevant predictions of river water quality?* Hydrological Processes, **36**(*4*). https://doi.org/10.1002/hyp.14565.

Urooj, A., Ilyas, R., Humayun, N. (2019*), Effects of Dumping Solid Waste on Water Quality of Surface Water Bodies.* Journal of Plant and Environment **1**(*1*)**,** pp. 21–24. doi: 10.33687/JPE.001.01.3575.

Received January 16, 2024