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Analysis of the Influence of Anthropogenic Factors of the Urbanized Territory of Poltava Region (Ukraine) on the State of River Water

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ABSTRACT

The analysis of anthropogenic factors influencing the state of natural water is carried out in the work. The need for a detailed study of the impact of urban areas on river water quality is noted. The study of the state of one of the main rivers of Poltava region in the area of about 100 km during the winter-spring period on the parameter of mineralization. The influence of individual settlements on the water status of the Vorskla River is considered. There was a gradual increase in river water pollution in the studied area and an increase in mineralization from 660 to 820 mg/l (February) and from 500 to 580 mg/l (April) (S_r = 2%). It was found that the greatest anthropogenic impact on the state of the Vorskla River is in the area of Poltava - Novi Sanzhary. The influence of surface runoff on changes in surface and groundwater quality of Poltava region is shown.

Keywords: anthropogenic factor, pollution, river, water quality, mineralization.

INTRODUCTION

Anthropogenic activity today is a factor that significantly changes the environment. Diverse human impact on the environment causes air pollution [Kustov et al.,2019; Wierzbińska et al., 2002], disturbance of soils [Lazaruk et al., 2020; Kostenko et al., 2018] and deterioration of water bodies [Loboichenko et al., 2021a; Akhtar et al., 2021]. In addition to direct human activities in cities, additional negative impact is provided directly by man-made emergencies [Popov et al., 2020; Mygalenko et al., 2018]. At the same time, usually, on the one hand, there is environmental pollution [Popov et al., 2019], and, on the other, there is the additional cost of natural resources (often water) to eliminate them [Abramov et al., 2019; Dubinin et al., 2018]. Although, it should be noted that the use of preventive measures [Pospelov et al., 2020], the use of calculated approaches

[Starodub et al., 2018], environmentally friendly methods of its elimination [Levterov, 2019; Stawczyk et al., 2021], clearly, can reduce the scale of the emergency or prevent its development.

At the same time, urbanization is also a factor that makes a significant contribution to environmental pollution, namely water bodies. Thus, the paper [Bhateria et al., 2016] notes the significant negative impact of human activities and urbanization on the state of lakes in India. There is a need for research on physicochemical parameters, such as the content of heavy metals, sulfates, nitrates, pH, conductivity, TDS, BOD and others. Discharges of industrial and municipal wastewater, climate change cause an increase in microplastics in water, further accumulation of heavy metals in living organisms, eutrophication of water bodies, increasing risks to human health who consume this water. It is noted that treatment methods should include, in addition to filtration and bioremediation, a ban on the discharge of pollutants into water bodies.

The impact of the urbanized area is considered in more detailed way for a number of water bodies in Popasna (Ukraine). Changes in the parameter of electrical conductivity under the influence of surface urban runoff were noted for a number of reservoirs of this city in the work [Loboichenko et al., 2021b]. The predominant influence of surface runoff on individual ponds in Popasna was noted. The improvement in the water quality in Lake Vembanad (India) by reducing the impact of anthropogenic factors and using remote sensing and in situ observations in the period of global pandemic caused by SARS-CoV-2 (2020 p) was noted in the work [Kulk et al., 2021]. Although the authors do not mention separate sources of pollution, they state the need for the remote monitoring of water status and the regulation of anthropogenic activities for sustainable management of Lake Vembanad.

Rivers are also one of the most important types of water bodies affected by humans. They are often the main source of water supply for settlements, as well as providing water to natural ecosystems at various levels. Surface runoff from the surrounding area, both from the urbanized and the intact one, also enters the river and increases the amount of soluble mineral and organic compounds. Municipal and industrial wastewater of various degrees of purification also gets into river water, additionally polluting it. Further deterioration of river water quality, obviously, negatively affects the life of all living organisms that use it. In turn, this indicates the need for a more detailed study of individual anthropogenic factors affecting the state of river water in order to further more efficient use of water resources and environmental protective measures.

The study of the state of water bodies, including river systems under anthropogenic pressure, has been considered by many researchers. Thus, the paper [Masere et al., 2012] notes that the state of Manyame River water is affected by surface runoff, wastewater and agriculture, which increases turbidity and nutrient content in it, and reduces the content of soluble oxygen. The interviews of residents of Nyamira County (Kenya) indicated a negative impact of untreated wastewater from households and direct washing in these rivers [Bosire et al., 2021] on the state of water in Gucha, Kenyamuchwachwa and Kenyamware rivers. The use of physico-chemical methods and multivariate statistical analysis, i.e., principle component analysis in the study Indus River (Pakistan) allowed to note that the main factors of pollution of its water are anthropogenic source pollution, runoff due to rain and soil erosion [Mansoor et al., 2019]. The changes in electrical conductivity, TDS, soluble oxygen and lead are due to the anthropogenic impact.

In the work [El-Shazly, 2019] the influence of anthropogenic factors on the wetland ecosystems of the Nile delta has been researched, in particular, the influence of anthropogenic factors on the physicochemical and biotic parameters of the three lakes Edku, Burullus and Manzala located in the Nile delta. The accumulation of heavy metals in surface sediments and in some representatives of fauna and flora (tilapia fish and the common reed) is noted, there is no similarity of their accumulation in water and bio samples, though.

When studying the state of water in the Vizela River (Portugal) by parameters pH, TDS, electrical conductivity, redox potential, and chloride, fluoride, bromide, nitrite, nitrate, sulfate, and phosphate content authors [Horta Ribeiro Antunes et al., 2021] noted that the most polluted water is downstream and unfit for human consumption according to the parameter NO_2^-. It is stated that the water of this river is affected by urbanization and industrialization. The general research of anthropogenic influence on a condition of surface waters is considered in the work [Khatri et al., 2015]. In particular, the heterogeneous impact of urbanized and rural areas on the state of these waters is noted.

The negative impact of anthropogenic factors in some areas of the Paranhana River (Southern Brazil) is noted by the authors [Dalzochio et al., 2019]. Thus, the study of water status according to physical- and- chemical, microbiological parameters and the biota status in two areas determined the excess of a number of heavy metals in the area, which is more urbanized, while the accumulation of heavy metals in fish is observed in both studied areas. The study of the state of the river according to the index of water pollution was conducted by Ukrainian scientists [Shuliakova et al., 2020]. In particular, anthropogenic impacts on water quality in the Southern Bug River (Ukraine) were noted in a number of areas in which the river flows. Thus, there is an excess of sulfate, chloride and ammonium ion in 15 studied points. Unsatisfactory operation of sewage treatment plants of communal enterprises, intensification of agricultural and industrial activities, and irrational management of water management activities are noted as the main factors of pollution. At the same time, the authors do not detail the specifics of the impact of individual anthropogenic sources and rely on official statistics.

Downstream cumulative effect of pollutants was observed in the study of the water status of the river Białka (southern Poland) [Bojarczuk et al., 2018]. There was a negative impact of the tourism industry on river water quality; the bacterial contamination occurred in all study areas, including the recreational area, though. There are non-point (surface runoff, melt water) sources of pollution related to the specifics of the region, it is not noted which point sources are also involved in polluted rivers, though. The gradual pollution of the Benin River (Nigeria) in a separate area between the two settlements of Ajimele and Koko town was noted by the authors in [Ayobahan et al., 2014] The use of the Water Quality Index and the principle component analysis made it possible to identify the most polluted areas downstream. It is also noted that the pollution of the river water is caused by organic pollution, industrial effluent, soil erosion, nutrient loading and human activities.

Multiparametric spatial and temporal study of water quality Nanfeihe River (China), conducted by the authors [Yang et al., 2021], indicates the need for careful selection of proper index to accurately trace the latent pollution sources of urban rivers. Thus, the City Water Quality Index is more informative than the Water Quality Index in determining potential pollution sources with heavy loads of pollutants.

The combination of the use of a number of physical and chemical parameters and various indices of water quality (pollution) with the use of cluster analysis, although a fairly extensive study, at the same time allowed to determine the possibility of using the water of the Tillai River (Bangladesh) for different water uses [Rahman et al., 2020]. This study also identified the main sources of river pollution. Thus, to study the state of water bodies and, in particular, rivers different approaches are used to assess both the complex and individual impact of individual sources of pollution, which further ensures better management of anthropogenic activities and optimize water use of these water sources.

The purpose of this work is to study the impact of anthropogenic factors in the urban area of Poltava region (Ukraine) on the state of the Vorskla River.

MATERIALS AND METHODS

Water samples were taken from water bodies (the Vorskla River (the samples were collected about 10 cm below the water level at a distance of 1.5–2.0 m from the shore) and groundwater (well)) during February – April 2021 in accordance with [ISO 5667-6:2014, DSanPiN 2.2.4-171-10] once a month. In February the samples were taken out from the ice-holes as the water had frozen.

Figure 1 shows the sampling points where points 1–12 are water of the Vorskla River, point 13 is groundwater (well). Studying the water of the Vorskla River, samples were taken in the Poltava-Kobeliaky section, downstream, taking into account the potential impact of certain anthropogenic factors.

Subsequently, the mineralization of water samples was measured. Number of measurements is 5 (for each water sample). The analysis was performed with a conductivity meter EZODO 7021. After each series of measurements, the instrument sensor was thoroughly rinsed with distilled water. Data processing was performed by standard statistical methods according to [Dvorkin, 2001]. The relative standard deviation (S_r), which is a characteristic of the measurement error, does not exceed 2 % for all determinations.

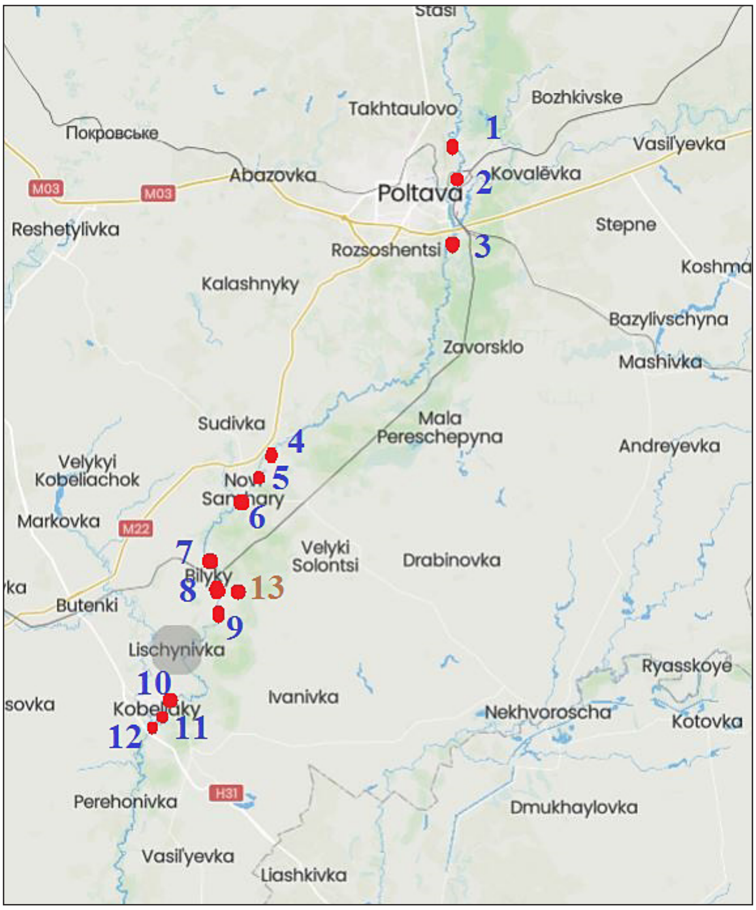

Fig. 1. Sampling points of the tested water. Points 1–12 are water of the Vorskla River, point 13 is groundwater (well)

RESULTS AND DISCUSSION

The influence of separate anthropogenic factors on the water condition of the Vorskla River (Poltava region, Ukraine, in the section Poltava - Kobeliaky, the length of which reaches about 100 km) was investigated. The Vorskla River is one of the medium-sized rivers in Ukraine; its length in the Poltava region reaches 226 km. It is used for recreational purposes and for drinking water supply [Regional report 2019].

Sampling points were selected in order to investigate the impact of individual settlements (Poltava, Novi Sanzhary, Bilyky, Kobeliaky, Kustolovi Kushchi) on the water status of the Vorskla River (Fig. 1). Point 1 is in front of Poltava 200 m upstream; point 2 is Poltava 100 m upstream in front of the road bridge, on the city beach; point 3 is behind the city of Poltava 700 m downstream behind the road bridge; point 4 is in front of the village of Novi Sanzhary 100 m upstream; point 5 is in the village of Novi Sanzhary 150 m downstream behind the road bridge, on the beach; point 6 is behind the village of Novi Sanzhary 100 m downstream; point 7 is in front of the village of Squirrels 200 m upstream; point 8 is in the village of Bilyky 200 m upstream in front of the road bridge; point 9 is behind the village of Bilyky 100 m downstream; point 10 is in front of the town of Kobeliaky 100 m upstream; point 11 is in the town of Kobeliaky 150 m downstream behind the road bridge; point 12 behind the town of Kobeliaky 100 m downstream, after the Kobeliachka River flows into the Voskla River. The groundwater sample (well in the village of Kustolovi Kushchi) (Fig. 1, point 13) was used as a reference.

In Figure 2 the obtained values of mineralization for water samples of the Vorskla River, taken from points 1–12 during the studied period, are given. Figure 3 shows the values of water mineralization of the reference sample (point 13) during the studied period. SanPiN 4630-88 was used as a standard [SanPiN 4630-88]. According to SanPiN 4630-88 the mineralization

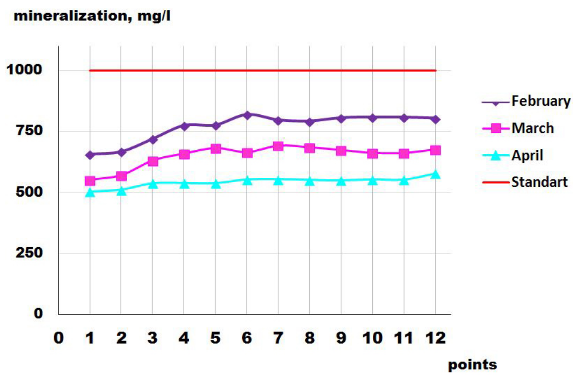

Fig. 2. Significance of mineralization of the water of the Vorskla River in the studied points (p. 1–12) during February - April 2021, mg/l

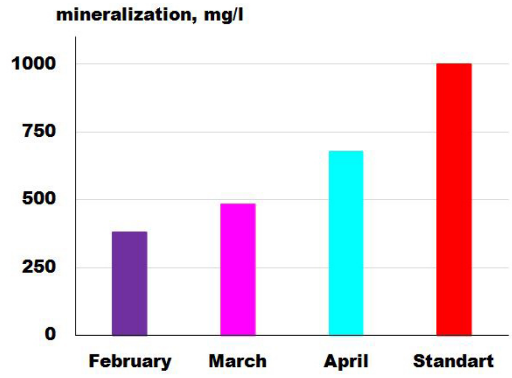

Fig. 3. The values of groundwater mineralization (well) (p. 13) for the period February - April 2021, mg/l

of natural water should not exceed 1000 mg/l. According to Figures 2 and 3 there is no excess of standard values for all tested samples. Mineralization is a characteristic of the content of soluble substances, which under conditions of anthropogenic load, are often pollutants.

According to the data obtained (Fig. 2), the purest water in the studied section of the Vorskla River is observed in front of the city of Poltava, then the content of pollutants begins to increase with fluctuations, and increases to the village of Novi Sanzhary. After passing the village Novi Sanzhary the value of mineralization is somewhat reduced. It is possible to assume that poor quality sewage treatment plants of Novi Sanzhary causes the ingress of insufficiently treated wastewater into the Vorskla River which is diluted with the river water, passing the village of Bilyky. Further the content of pollutants in the Vorskla River remains virtually unchanged in the town of Kobeliaky. This dependence is more characteristic for February, for April it is also observed, but without such sharp differences as for February and with a small increase in mineralization after tflowing the Kobelyaki River into the Vorskla River (Fig. 2, p. 12).

For March, on the contrary, there is a decrease in mineralization after passing the city of Sanzhary (Fig. 2, p. 6), which may indicate a temporary intensification of wastewater treatment in the village of Novi Sanzhary. Further increase and decrease of mineralization may indicate a significant role of surface runoff (meltwater) on the importance of mineralization in the area of Novi Sanzhary and Kobeliaky, although there is an impact of water on the Kobeliaky River (Fig. 2, p. 12).

According to Figure 2, the highest values of mineralization are typical for February. There is an increase from 660 mg/l to 820 mg/l in the area of Poltava and Novi Sanzhary and from 800 mg/l to 810 mg/l in the area of Bilyky and Kobeliaky. The lowest values of mineralization are observed for April. Thus, it increases from 500 mg/l to 555 mg/l in Poltava and Novi Sanzhary section, and from 550 mg/l to 580 mg/l in Bilyky and Kobeliaky section. Consequently, despite the impact of meltwater (March, April) the predominant factor, influencing the water status of the Vorskla River in the studied area, is anthropogenic factors, in particular, the activities of settlements. There is a predominant impact of the city of Poltava and the village of Novi Sanzhary on the water quality of the Vorskla River. There is a gradual increase of pollution in the river water in the studied area and an increase of mineralization from 660 mg/l to 820 mg/l (February) and from 500 mg/l to 550 mg/l (April) in Poltava and Novi Sanzhari section. There is a slight impact of the Kobeliaky River in March and April on the water pollution in the Vorskla River.

For the reference sample (Fig. 3), there is a gradual increase in mineralization from 380 mg/l to 680 mg/l from February to April, probably due to the gradual infiltration of pollutants from meltwater and their ingress into groundwater. Given the data obtained (Fig. 2 and Fig. 3), we can assume that the lower mineralization values are more typical for the studied groundwater than for surface water.

Taking into account the obtained results, it is recommended to strengthen the control of local governments over wastewater treatment in Poltava and the village of Novi Sanzhary in order to improve the water condition of the Vorskla River for more rational use of water resources.

CONCLUSIONS

Thus, it was found that anthropogenic activities, especially within urban areas, have different effects on the state of water bodies, and, in particular, rivers. Physical-and-chemical, microbiological indicators, biota status studies, etc. are used to study this effect, using various indices and mathematical methods of data processing.

The spatial and temporal study of the water status of the Vorskla River (Poltava region) showed that despite the impact of meltwater (March, April 2021), the predominant factor influencing the water status of the Vorskla River in the studied area is anthropogenic factor, in particular, and the activities of settlements. There is a predominant impact of the activities of Poltava and the village Novi Sanzhary on the water quality of the Vorskla River. There is a gradual increase of pollution in the river water in the studied area and an increase of mineralization from 660 mg/l to 820 mg/l (February) and from 500 mg/l to 550 mg/l (April) in Poltava and Novi Sanzhari section, there is a slight impact of the Kobeliak River in March-April on water pollution in the Vorskla River.

For the studied groundwater, there is a gradual increase of mineralization, probably due to the infiltration of pollutants from the meltwater and their entry into groundwater. It can be assumed that this water is less characterized by lower mineralization values than for surface water (Vorskla River). It is recommended to strengthen the control of local governments over wastewater treatment in Poltava and Novi Sanzhary in order to improve the water condition of the Vorskla River for more rational use of water resources.

REFERENCES

1. Abramov Y., Basmanov O., Salamov J., Mikhayluk A., Yashchenko O. 2019. Developing a model of tank cooling by water jets from hydraulic monitors under conditions of fire. Eastern-European Journal of Enterprise Technologies, 1(10–97), 14–20. https://doi.org/10.15587/1729-4061.2019.154669
2. Akhtar N., Syakir Ishak M.I., Bhawani S.A., Umar K. 2021. Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. Water, 13, 2660. https://doi.org/10.3390/w13192660
3. Ayobahan S.U., Ezenwa I.M., Orogun E.E., UrirI J.E., Wemimo I.J. 2014. Assessment of Anthropogenic Activities on Water Quality of Benin River. Journal of Applied Sciences and Environmental Management, 18(4), 629–636. DOI: 10.4314/jasem.v18i4.11
4. Baluch M.A., Hashmi H.N. 2019. Investigating the Impact of Anthropogenic and Natural Sources of Pollution on Quality of Water in Upper Indus Basin (UIB) by Using Multivariate Statistical Analysis. Journal of Chemistry, 13. https://doi.org/10.1155/2019/4307251
5. Bhateria R., Jain D. 2016. Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2, 161–173. https://doi.org/10.1007/s40899-015-0014-7
6. Bojarczuk A., Jelonkiewicz Ł., Lenart-Boroń A. 2018. The effect of anthropogenic and natural factors on the prevalence of physicochemical parameters of water and bacterial water quality indicators along the river Białka, southern Poland. Environmental science and pollution research international, 25(10), 10102–10114. https://doi.org/10.1007/s11356-018-1212-2
7. Bosire A.S., Nyantika D., Mamboleo D. 2021. Evaluation of the effects of human activities on water resources in Masaba North, Nyamira County. International Journal of Research and Scholarly Communication, 4(2). https://royalliteglobal.com/ijoras/article/view/690
8. Dalzochio T., Souza M.S. de, Simões L.A.R., Silva G.J.H., Rodrigues G.Z.P., Andriguetti N. B., Silva L.B. da, Gehlen G. 2019. Impact of Anthropogenic Activities on Water Quality of The Paranhana River, Southern Brazil. Brazilian Archives of Biology and Technology, 62, e19180523. https://doi.org/10.1590/1678-4324-2019180523
9. DSanPiN 2.2.4–171–10 Hygienic requirements for drinking water intended for human consumption. Order of the Ministry of Health Protection of Ukraine dated 12.05.2010 No. 400. URL: https://zakon.rada.gov.ua/laws/show/z0452–10#Text (in Ukrainian).
10. Dubinin D., Korytchenko K., Lisnyak A., Hrytsyna I., Trigub V. 2018. Improving the installation for fire extinguishing with finelydispersed water. Eastern-European Journal of Enterprise Technologies, 2(10–92), 38–43. https://doi.org/10.15587/1729-4061.2018.127865
11. Dvorkin V.I. 2001. Metrology and quality assurance of quantitative chemical analysis, Chemistry, Moscow. (in Russian)
12. El-Shazly M.M. 2019. The impact of some anthropogenic activities on river Nile delta wetland ecosystems. Global Journal of Ecology, 4(1), 1–7. DOI: 10.17352/gje.000008
13. Horta Ribeiro Antunes I.M., Brás A.F., Reis A.P.M. 2021. Surface Water and Contamination Sources in Urban River Watersheds (Northern Portugal). Ecological Engineering & Environmental Technology, 22(2), 67–74. DOI: 10.12912/27197050/133327

14. ISO 5667-6:2014. Water quality — Sampling — Part 6: Guidance on sampling of rivers and streams.
15. Kostenko V., Zavialova O., Chepak O., Pokalyuk V. 2018. Mitigating the adverse environmental impact resulting from closing down of mining enterprises. Mining of Mineral Deposits, 12(3), 105–112. https://doi.org/10.15407/mining12.03.105
16. Kustov M., Slepuzhnikov E., Lipovoy V., Khmyrov I., Firdovsi D., Buskin O. 2019. Procedure for implementation of the method of artificial deposition of radioactive substances from the atmosphere. Nuclear and Radiation Safety, 3(83), 13–25. (in Ukrainian) https://doi.org/10.32918/nrs.2019.3(83).02
17. Khatri N., Tyagi S. 2015. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. Frontiers in Life Science, 8(1), 23–39, DOI: 10.1080/21553769.2014.933716.
18. Kulk G., George G., Abdulaziz A., Menon,N., Theenathayalan V., Jayaram C., Brewin R.J.W., Sathyendranath S. 2021. Effect of Reduced Anthropogenic Activities on Water Quality in Lake Vembanad, India. Remote Sensing, 13, 1631. https://doi.org/10.3390/rs13091631
19. Lazaruk Y., Karabyn V. 2020. Shale gas in Western Ukraine: Perspectives, resources, environmental and technogenic risk of production. Petroleum and Coal, 62(3), 836–844.
20. Levterov A.A. 2019. Acoustic Research Method for Burning Flammable Substances. Acoustical Physics, 65(4), 444–449. DOI: 10.1134/S1063771019040109
21. Loboichenko V., Leonova N., Shevchenko R., Kapustnik A., Yeremenko S., Pruskyi A. 2021a. Assessment of the Impact of Natural and Anthropogenic Factors on the State of Water Objects in Urbanized and Non-Urbanized Areas in Lozova District (Ukraine). Ecological Engineering & Environmental Technology, 22(2), 59–66. https://doi.org/10.12912/27197050/133333
22. Loboichenko V., Leonova N., Shevchenko R., Strelets V., Morozov A., Pruskyi A., Avramenko O., Bondarenko S. 2021b. Spatio-Temporal Study of the Ecological State of Water Bodies Located within the Detached Objects of the Urbanized Territory of Ukraine. Ecological Engineering & Environmental Technology, 22(6), 36–44. https://doi.org/10.12912/27197050/141610
23. Masere T.P., Munodawafa A., Chitata T. 2012. Assessment of human impact on water quality along Manyame River. International Journal of Development and Sustainability, 1(3), 754–765. https://isdsnet.com/ijds-v1n3-10.pdf.
24. Mygalenko K., Nuyanzin V., Zemlianskyi A., Dominik A., Pozdieiev S. 2018. Development of the technique for restricting the propagation of fire in natural peat ecosystems. Eastern-European Journal of Enterprise Technologies, 1(10–91), 31–37. https://doi.org/10.15587/1729-4061.2018.121727.
25. Popov O., Iatsyshyn A., Kovach V., Artemchuk V., Taraduda D., Sobyna V., Sokolov D., Dement M., Yatsyshyn T., Matvieieva I. 2019. Analysis of possible causes of NPP emergencies to minimize risk of their occurrence. Nuclear and Radiation Safety, 1(81), 75–80. DOI: https://doi.org/10.32918/nrs.2019.1(81).13.
26. Popov O., Taraduda D., Sobyna V., Sokolov D., Dement M., Pomaza-Ponomarenko A. 2020. Emergencies at Potentially Dangerous Objects Causing Atmosphere Pollution: Peculiarities of Chemically Hazardous Substances Migration. In: Babak V., Isaienko V., Zaporozhets A. (eds) Systems, Decision and Control in Energy I. Studies in Systems, Decision and Control. Springer, Cham, 298, 151–163. https://doi.org/10.1007/978-3-030-48583-2_10 .
27. Pospelov B., Kovrehin V., Rybka E., Krainiukov O., Petukhova O., Butenko T., Borodych P., Morozov I., Horbov O., Hrachova I. 2020. Development of a method for detecting dangerous states of polluted atmospheric air based on the current recurrence of the combined risk. Eastern-European Journal of Enterprise Technologies, 5(9–107), 49–56. https://doi.org/10.15587/1729-4061.2020.213892.
28. Rahman M.M., Howladar M., Hossain A., Muzemder A.S.H. and Numanbakth A.A. 2020. Impact assessment of anthropogenic activities on water environment of Tillai river and its surroundings, Barapukuria thermal power plant, Dinajpur, Bangladesh. Groundwater for Sustainable Development, 10, 100310. https://doi.org/10.1016/j.gsd.2019.100310.
29. Report 2019. Regional report on the state of the environment in the Poltava region in 2019. Poltava 2020. Report 2019 Department of Ecology and Natural Resources. URL: https://mepr.gov.ua/files/docs/Reg.report/2019/%D0%9F%D0%BE%D0%BB%D1%82%D0%B0%D0%B2%D1%81%D1%8C%D0%BA%D0%B0%20%D0%BE%D0%B1%D0%BB%D0%B0%D1%81%D1%82%D1%8C.pdf
30. SanPiN 4630-88. Sanitary rules and norms for the protection of surface waters from pollution. Verkhovna Rada of Ukraine. Official site. URL: https://zakon.rada.gov.ua/laws/show/v4630400-88#Text.
31. Shuliakova M.G., Mykhaylenko V.P. 2020. The Influence of anthropogenic factors on water quality in the Southern Bug River basin. Physical Geography and Geomorphology, 101–102, 41–51. https://doi.org/10.17721/phgg.2020.3-4.05 (in Ukranian)
32. Starodub Y., Karabyn V., Havrys A., Shainoga I., Samberg A. 2018. Flood risk assessment of Chervonograd mining-industrial district. Proc. SPIE 10783, 107830P. Event SPIE. Remote Sensing. https://doi.org/10.1117/12.2501928.

33. Stawczyk P., Wilk-Jakubowski J. 2021. Non-invasive attempts to extinguish flames with the use of high-power acoustic extinguisher, Open Engineering, 11(1), 349–355, DOI: 10.1515/eng-2021-0037.
34. Wierzbińska M., Adamus A. 2020. Impact of the type of fuel burned and the heating device on the quality of atmospheric air. Ecological Engineering & Environmental Technology, 21(1), 17–25. https://doi.org/10.12912/23920629/120380
35. Yang S., Liang M., Qin Z., Qian Y., Li M., Cao Y. 2021. A novel assessment considering spatial and temporal variations of water quality to identify pollution sources in urban rivers. Scientific reports, 11. https://doi.org/10.1038/s41598-021-87671-4.