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Manifestations and consequences of water conflicts: case study of the Pechenihy reservoir, Kharkiv region, Ukraine

Kateryna Borysenko [1]
PhD (Pedagogy), Associate Professor of the Department of Physical Geography and Cartography,
[1] V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,
e-mail: k.borysenko@karazin.ua, http://orcid.org/0000-0002-7435-6857;
Simon M. Hutchinson [2]
PhD (Palaeolimnology), Associate Professor, School of Sciences, Engineering and Environment,
[2] University of Salford, Salford, United Kingdom,
e-mail: s.m.hutchinson@salford.ac.uk, https://orcid.org/0000-0003-0072-1062;
Diana Sinchuk [1]
BSc student, Department of Physical Geography and Cartography,
e-mail: dsincuk3@gmail.com, https://orcid.org/0009-0001-1215-7481

ABSTRACT

Statement of the problem. The article discusses the manifestations and consequences of such conflicts, in particular their impact on the Pechenihy Reservoir. The study of the problem of water clashes and its exhaustive justification is an important step in the development of effective strategies for managing water resources and preventing the negative consequences of conflicts. Despite the generally defined interpretation of water conflicts, the term should be considered more thoroughly as a phenomenon, based on its duality, because such conflicts can be provoked by different reasons, and therefore their course and consequences may differ. The study of the problem of water clashes and its exhaustive justification is an important step in the development of effective strategies for managing water resources and preventing the negative consequences of conflicts. The study of the problems of water conflicts with the example of the Pechenihy reservoir is due to the novelty of the problem faced by this reservoir. For the first time, the Pechenihy reservoir witnessed large-scale hostilities and, accordingly, for the first time in the history of its existence, faced the devastating consequences of the war. A comprehensive characterization of the reservoir as a center of local water skirmish is necessary, especially in the context of determining the manifestations and classifications of water conflicts.

The aim of the work is to set out the causes, classifications and consequences of water conflicts that arise in the context of the use of water resources based on the example of the Pechenihy reservoir. The article aims at a comprehensive analysis of the impact of these conflicts on the geo-ecological and social spheres.

Methods. In addition to general scientific methods of analysis, synthesis and generalization, geographical methods of research were used. A special place was occupied by the methods of space hydrology (deciphering aerospace images of the reservoir). The applied method of system analysis helped to identify and clearly classify the situation around the studied reservoir as a local water conflict with the identification of the problem and the way of its course.

Results. The study substantiates the phenomenon of water conflicts, highlighting their dual nature as both geo-ecological and social issues, exacerbated by military operations. The hydrological and technical characteristics of the Pechenihy reservoir were examined, revealing significant geo- and hydroecological problems due to nearby combat activities. The study provides a first-time analysis of local water conflict events from the onset of the Russian invasion to the Kharkiv counteroffensive, classifying the conflict around the Pechenihy reservoir as armed, with water serving as both a victim and weapon.

The novelty of this article is manifested in an in-depth study of the specifics of hydroecological conflicts in the conditions of long-term hostilities around the Pechenihy reservoir, followed by a comprehensive analysis of the geoecological and social aspects of this problem.

Keywords*: water conflicts, Pechenihy reservoir, hostilities, hydrological resources, geoecological state.*

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Statement of the problem. Water conflicts are a rather dangerous, both environmental and social problem of our time, exacerbated by climate change and inevitable population growth. Despite the generally defined interpretation of water conflicts, the term should be considered more thoroughly as a phenomenon, based on its duality, because such conflicts can be provoked by different reasons, and therefore their course and consequences may differ. Pechenihy Reservoir is an important hydrological resource, which ensures sustainable water supply for the population and the city of Kharkiv and other communities in the region. However, after the start of the full-scale invasion by Russia in 2022, it has faced armed violence, which has negatively affected the hydro-ecological balance of the reservoir. Water conflicts can have serious consequences, both for the ecosystem of a water body and for the socio-economic well-being of the population. The article discusses the manifestations and consequences of such conflicts, in particular their impact on the water body under study. The study of the problem of water

clashes and its exhaustive justification is an important step in the development of effective strategies for managing water resources and preventing the negative consequences of conflicts. The study of the problems of water conflicts with the example of the Pechenihy reservoir is due to the novelty of the problem faced by this reservoir. For the first time, the Pechenihy reservoir witnessed large-scale hostilities and, accordingly, for the first time in the history of its existence, faced the devastating consequences of the war. A comprehensive characterization of the reservoir as a center of local water skirmish is necessary, especially in the context of determining the manifestations and classifications of water conflicts.

Analysis of major research and publications. Domestic scientists have long paid attention to water conflicts around the water bodies of Ukraine and its irrigated lands. It is worth mentioning the studies by V. Peleshenko and L. Gorev concerning the use of the waters of the Kakhovka reservoir via the South-Ukrainian Canal and a complex network of canals for the irrigation and watering of the Southern Steppe [12,16]. These researchers examined the ecological and hydrochemical problems of irrigation of these lands, thoroughly studying the negative processes of salinization accompanying irrigation and the loss of fertility of soils under irrigation [13,14]. Professor Georgiy Dubinsky of V. N. Karazin Kharkiv National University, in cooperation with the Ukrainian Hydrometeorological Institute (UHMI), developed the basics of irrigation service based on monitoring the dynamics of the hydrothermal index, which determines the ecological state of fields. According to his calculations, the use of such a monitoring service would save irrigation water several times from the existing irrigation norms at that time, which would also help reduce the risks of waterlogging of the soil and conflicts between irrigated agriculture and competitive areas of nature management. In addition, the Kharkiv Hydrological Center has many hydroecologists, whose works are devoted to integrated planning of the use and management of water resources, the understanding of which is a very important link in avoiding water clashes. They include O. Vasylenko [19], G. Vernychenko [20] and S. Anasimova [21].

These are also numerous studies derived from Taras Shevchenko National University of Kyiv. Among the most prominent figures in this field is Valentyn Khilchevskyi, the head of the scientific hydrochemical school of the Kyiv National University. In addition to a number of hydrological studies, he devoted his works to the generalization and study of water conflicts in different regions of Ukraine, especially in the Donbas, and also highlighted the classification features of such conflicts in the world and in Ukraine. Other domestic researchers include I. Losovsky [12], S. Ivaniuta [11], V. Horbulin and S. Mosov [9].

The most well-known figure in the study of general problems of water conflicts is the American scientist Peter Gleick, who in the 1990s proposed the first classification of such conflicts and traced the cause-and-effect relationships of their occurrence [3]. Today his research is fundamental for many hydrologists who continue to study the phenomenon of water conflicts. The world's most famous institution that researches and documents water clashes is the Pacific Institute for Environmental Development and Security Research, whose founder and current president is the aforementioned Peter Gleick [7].

Water skirmishes are explored in different parts of the world including:

1. Masahiro Murakami, co-authored with Libor Jansky, investigated the consequences of the controversial Gabčíkovo-Nagymaros project on the Danube between Hungary and Slovakia [4];

2. Ashoka Swainu, who researched water disputes over the Ganges [5];

3. Kemal Başlar, who in his works explored the disputes around the Aegean Sea [1];

4. Taikana Oki, who studied the economic consequences of water conflicts for the population [6], and many others.

An unresolved part of the overall problem. Research of water conflicts also includes the study of consequences and further prospects for recovery. Currently, there are new studies related to the consequences of the Russian-Ukrainian armed conflict on water resources and water infrastructure in general. O. Shumilova, H. Trokhymenko and S. Stepanenko, in co-authorship with V. Khilchevsky and P. Gleik [22], studied the impact of hostilities on water bodies of Ukraine and the features of these water conflicts. V. Strokal and A. Kovpak [15] investigated the environmental consequences of hostilities on water bodies, systematized certain manifestations of these disputes and classified them according to the nature of hostilities and the level of aggravation. In general, the experience of studying water conflicts includes many works on various clashes around the world. The phenomenon of water conflicts, unfortunately, is on-going, so their further study will always be relevant, and scientific papers will serve as an inexhaustible source and archival documentation of some water clashes.

Water conflicts are found in almost all corners of the world, as it is a significant threat to the sustainable use of water resources. The main problem of water conflicts is the lack of clear uniformity of classifications of its manifestations and, accordingly, solutions to the consequences. A water skirmish can be either a three-day local conflict at the level of a

conditional territorial community, provoked by the pollution of a water body, or a protracted war between two countries for the right to own a particular river. Such a discrepancy is outlined by a primitive and somewhat simplified definition, which is most often omitted when describing the conflict, giving preference to the social causes of its occurrence.

The aim of the work is to set out the causes, classifications and consequences of water conflicts that arise in the context of the use of water resources based on the example of the Pechenihy reservoir. The article aims at a comprehensive analysis of the impact of these conflicts on the geo-ecological and social spheres.

The novelty of this article is manifested in an in-depth study of the specifics of hydroecological conflicts in the conditions of long-term hostilities around the Pechenihy reservoir, followed by a comprehensive analysis of the geoecological and social aspects of this problem.

Materials and methods. The initial data to determine the ecological state of the reservoir after the cessation of hostilities near its shores were obtained from the Laboratory at the Regional Office of Water Resources of the Kharkiv region. To map regional water conflicts, data from the open service Pacific Institute [7] were used, which contains a chronological list of recorded water clashes around the world. All cartographic materials were produced in the ArcMap 10.8 GIS environment.

In addition to general scientific methods of analysis, synthesis and generalization, geographical methods of research were used. A special place was occupied by the methods of space hydrology [18]. Thanks to satellite images, it is possible to obtain accurate information about the morphometric indicators of a water body, the configuration of the basin, and they also make it possible to remotely monitor changes in the hydrological state and its features, based on different spectra of satellite images. With the help of deciphering aerospace images of the reservoir of the Pechenihy reservoir, the increase in the coastline due to the undermining of part of the dam structure was traced and analyzed, and the scale of its shallowing was determined using NDMI spectrum images.

The applied method of system analysis helped to identify and clearly classify the situation around the studied reservoir as a local water conflict with the identification of the problem and the way of its course. The use of this method made it possible to consider all aspects of the problem in their interconnection and interaction, which contributed to the identification of the main causes of conflicts and the development of effective strategies for their solution. The method of hydrological-geographical generalization made it possible to systematize and summarize data from the Pechenihy reservoir and its use, as well as to assess the impact of water conflicts on the sustainability of its hydro-ecological environment. The use of this method in the study made it possible to comprehensively assess the situation of the water skirmish around the Pechenihy reservoir, with the determination of its prerequisites and the scale of consequences.

Understanding water conflicts. Water resources are quite vulnerable to the impact of military conflicts. The level of potential distruption is detemined by the possible damage that can be caused by warfare and the consequences arising from water disputes and hostilities in general. According to the classification of the Pacific Institute, introduced by P. Gleick, «water» as part of a water conflict falls into three categories: «trigger», «victim» and «weapon» (Fig. 1). A similar classification of water conflicts was also considered by V. Khilchevskyi.

Water disputes can also be classified according

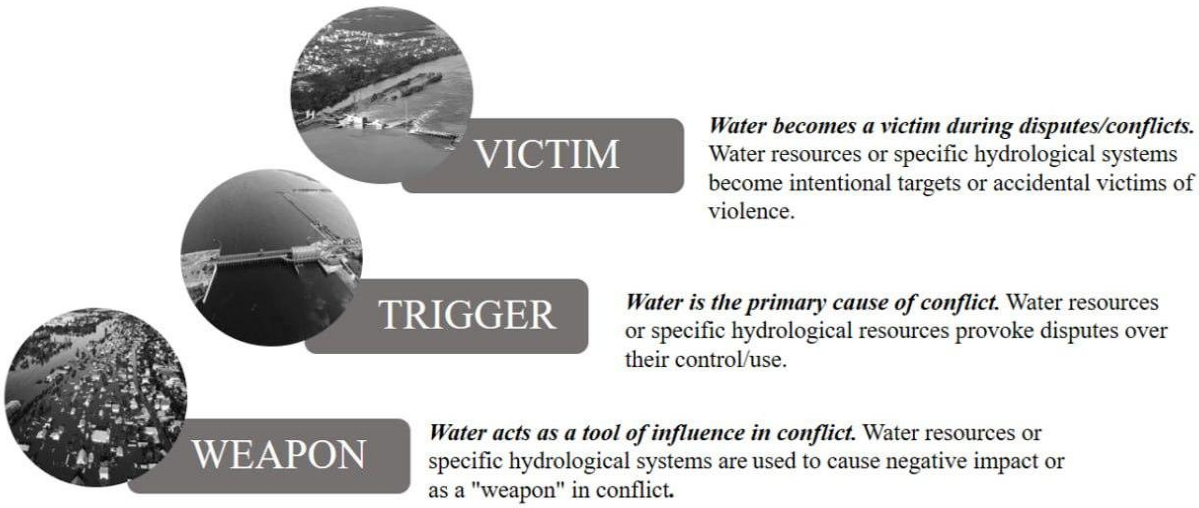

Fig. 1. Classification of types of water conflicts

to the form of the conflict – military and non-military; by the scale of the impacting activity – local, regional, national, cross-border; by the nature of the military activity eg., mining, surface explosions and seizure [17]. The presented classifications will allow a better understanding of the phenomenon of water conflict, the causes of their occurrence and methods of settlement.

When considering the causes, the phenomenon of water conflicts should be considered from two main aspects – the place of water and the place of people in the conflict. Based on this, the nature of such conflicts can be divided into two conditional categories: natural and anthropogenic. However, for the most part, both in the first and in the second case, water bodies become victims that are adversely affected. For example, natural factors include the uneven distribution of water resources over a territory. The second category includes the pollution of water sources, which can cause social protests due to its impact on the environment. Many rivers and lakes cross the borders of different countries, and this can also serve as a trigger for conflicts between states over the use and regulation of shared water resources.

When considering the basic prerequisites for water conflicts, it is necessary to rely on the place of water bodies in them, that is, to determine them based on the well-known classification of «trigger», «weapon», «victim».

The emergence of conflicts in the «trigger» classification can be provoked by two economic and sometimes human-provoked reasons – uneven access of the population to water and different purposes of use of stakeholders in relation to a certain hydrological object. It can be said that water conflicts, which began due to interest in certain hydroresources, are mostly caused by the anthropogenic factor. It is worth noting that the main trigger for this is the mismatch of people's interests in the use of certain water resources. Water in such conflicts most often takes the place of the victim and can develop into a weapon in the course of the conflict. Obviously, this significance of the water conflict explains it as a social conflict that affects a hydrological object.

The causes of water clashes, classified as «weapons», are also closely related to human activities, which have more catastrophic consequences. For the most part, these clashes arise during the course of armed conflicts. The use of hydrological resources for military purposes is a common battle strategy that gives one side a significant advantage. Unfortunately, this advantage has an exorbitant price for the civilian population and even greater for the water body that was used as a "weapon". World history has many similar cases. Examples include the blowing up of a cascade of dams on the Yellow River in 1938 by Chinese troops to delay the advance of the Japanese army, or the capture of the Fallujah dam by ISIS rebels in 2014 providing a strategic advantage over government forces. They are accompanied by the destruction of hydraulic structures and disturbance of the tranquility of certain hydrological systems of objects.

Based on the above, the phenomenon of water conflicts should be considered from two sides – social and natural. As a social phenomenon, water conflict is a dispute between two parties over access and use of hydrological resources. In turn, these disputes are negative processes for ecosystems of water resources, interpreting this phenomenon from a natural point of view. That is, regardless of whether water is a «trigger» or a «weapon», it is still an object of interest for two stakeholders who have different visions of its use. And more often than not, this object of interest becomes a «victim» and not just a root cause and tool. Water bodies in such conflicts undoubtedly suffer more damage than the conflicting parties, which would have some benefits under the conditions of peaceful use of these water resources. The causes of water conflicts classified as «victims» are mostly the result of human actions, which may overlap with other water conflicts of the «trigger» and «weapon» classifications.

To date, the largest number of water conflicts is recorded in the region of Asia and Africa. The aggravation of the conflict is primarily due to the shortage of water resources in regions that are low in local hydrological resources and the factor of transboundary location of certain «trigger» water bodies. The Pacific Institute database indicates that between 2000 and 2022 alone, about 900 cases of various water conflicts were recorded. The history of water disputes includes more than 1220 cases, among which 581 skirmishes are classified as «Trigger», 624 as «Victim» and 187 as «Weapon» [17].

According to the Pacific Institute database, the history of Ukrainian water conflicts includes approximately 47 skirmishes, of which 41 are classified as «victims» and 6 as «weapons». It is noteworthy that there are no recorded water conflicts classified as a «trigger» in Ukraine. This means that the impact of water conflicts is not typical for Ukrainian society, which indicates a competent structure of water supply to the population.

The very first water conflict in Ukraine, which was recorded in the database of the Pacific Institute, dates back to 1941. The strategically important Dnieper Hydroelectric Power Plant was targeted by both Soviet and German troops during the fighting of World War II. On August 18, 1941, Soviet troops retreating in front of the advancing German troops blew up the dam and the power plant. And in 1943,

the Dnieper Hydroelectric Power Plant was bombed again, but this time by retreating German troops. This fight can be classified as a «victim» and a «weapon» at the same time. Such «dual» classifications of conflicts in Ukraine are quite common, because when water resources are used as a «weapon», they automatically become a «victim».

A significant majority of the above number of disputes arose between 2014 and 2023. That is, it is possible to draw an indirect connection between the aggravation of the problem of water conflicts and Russia's attack on Ukraine (Fig. 2).

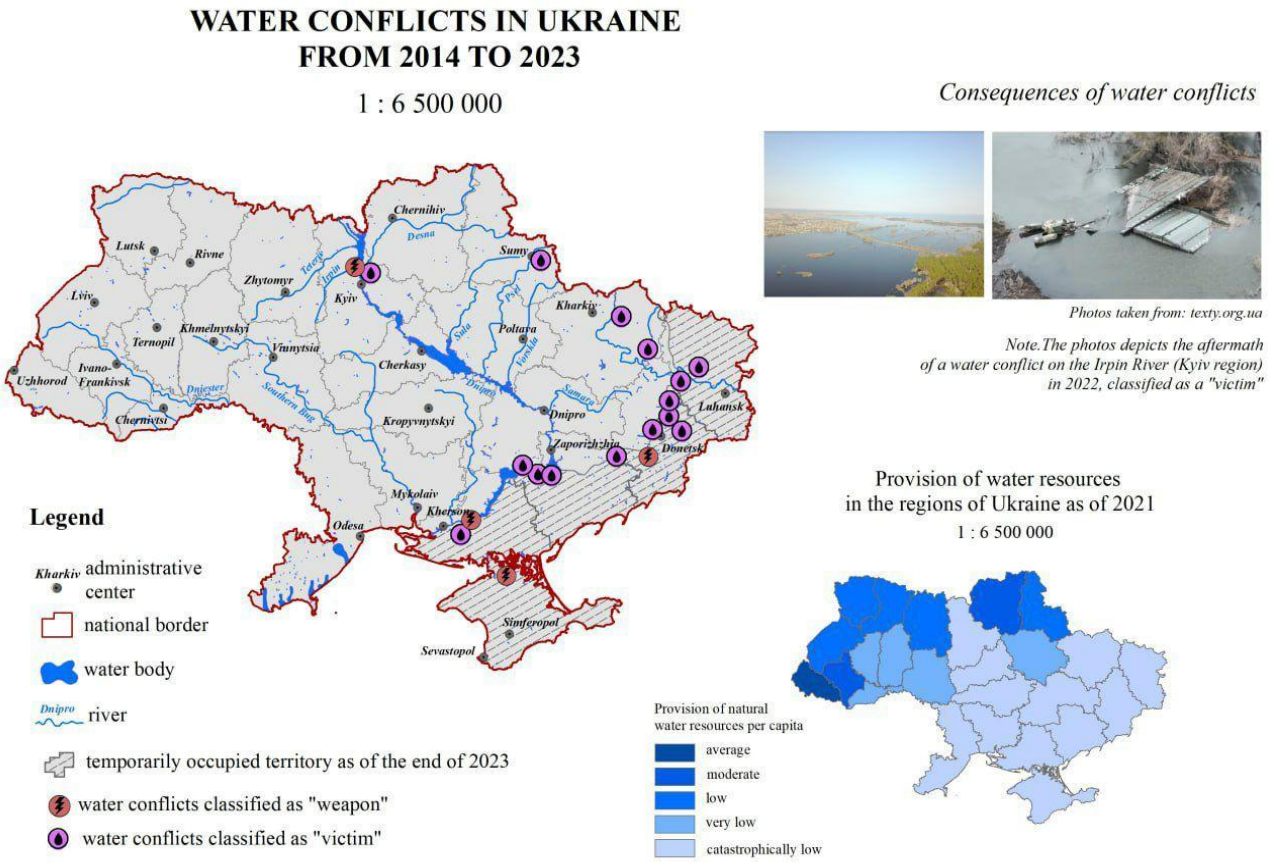

Fig. 2. Location of Ukrainian water conflicts in the period from 2014 to 2023

According to Fig. 2, it is possible to trace a certain pattern of occurrence and localization of water conflicts. Most of them arise near the front line, or territories where hostilities previously took place. If we take into account the additional inset map, we can conclude that water conflicts arise in areas with low availability of local hydrological resources and, accordingly, are even more dangerous in the context of water supply. Such actions are cynical and cruel not only against water resources, but also against the civilian population.

Case study of the Pechenihy reservoir. The construction of the Pechenihy reservoir began in 1958 with the construction of a bridge over the Siverskyi Donets River. Later a concrete plant was constructed immediately adjacent to the future dam, where there was plenty of sand, and in order to quickly supply concrete for construction (Fig. 3). The purpose of the reservoir is drinking water supply, irrigation and fish farming.

The reservoir is located in the northeastern part of the Kharkiv region. The dam is located 445 m. northeast of the village of Pechenihy. The reservoir belongs to the channel type, characterized by an elongated shape and a relatively small area of coastal shallow water zones (Fig. 4). The total length of the reservoir is 65 kilometers, the width is from 0.3 to 4 kilometers. The depth of the reservoir ranges from 2.5 to 14 meters. The volume of the Pechenihy reservoir is 400 million cubic meters.

The situation around the Pechenihy Reservoir as a result of the start of a full-scale invasion of the country in 2022 can be called one of the manifestations of water conflicts that has a double classification. It is worth noting that this is the first armed conflict that impacted the Pechenihy reservoir. For more than 50 years of its existence, the reservoir has never been subjected to military influence and, accordingly, has never become the site of a water conflict.

From the first days of the full-scale invasion of Ukraine by the Russian Armed Forces, the Pecheni-

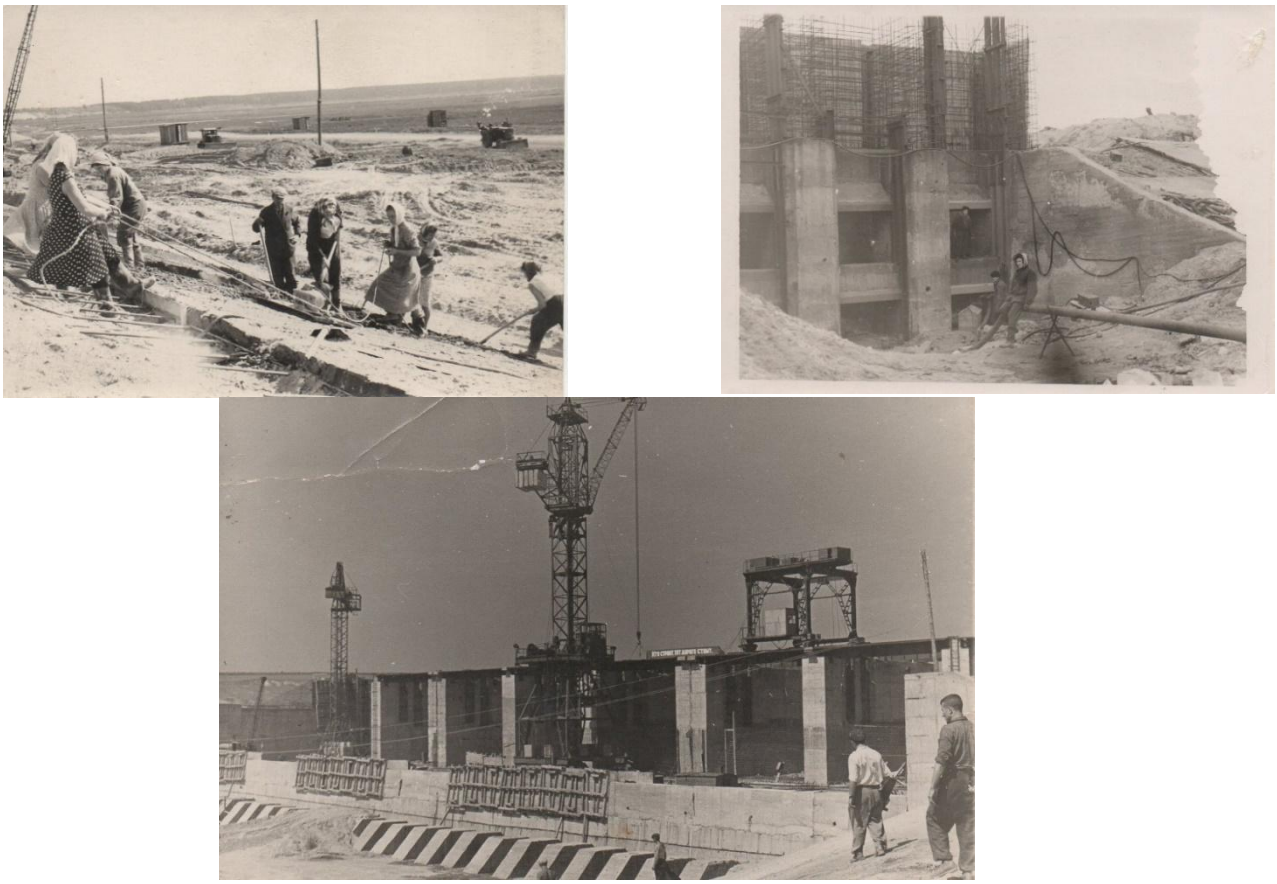

Fig. 3. Archival photos of the construction of the Pechenihy reservoir from the Museum of Local Lore of the Pechenihy district. (Source: T. A. Sulima)

Fig.4. Satellite images of the Pechenihy reservoir. The first one is a composite of natural colors (True Color). The second one is presented in a composite of artificial colors (False Color). Scale 1:400 000 [2]

hy Reservoir suffered from explosions and combat clashes taking place nearby. In the first days of the war (February 24-25, 2022), a tank battle took place on the shoreline of the reservoir, near the hydroelectric complex, as a result of which the Ukrainian side blew up part of the roadway to prevent the further offensive of Russian troops (Fig. 5) [8].

Subsequently, the reservoir has served as a line of demarcation for the front in the north-eastern part of the Kharkiv region, which is clearly visible on the map of hostilities near the downstream of the Pechenihy reservoir (Fig. 6).

The greatest damage to the hydraulic structure was caused in September 2022. Three locks were taken out of working order by a missile strike, two of which were completely destroyed. As of November 2023, only three of the dam's eight locks are in operation (Fig. 7). The overflow of the river and the

Fig. 5. Parts of the hydraulic structure as of 25.02.2022. Photos taken by news channels

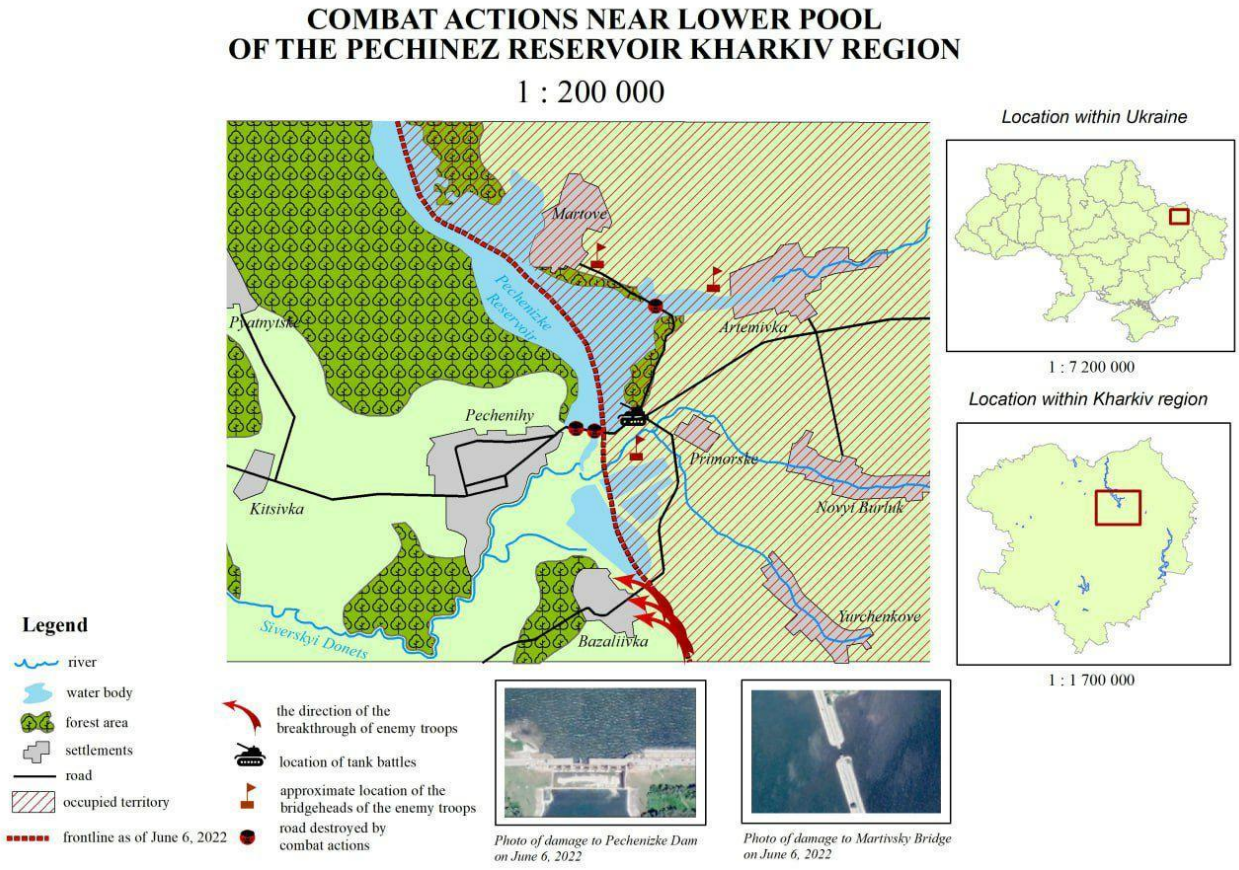

Fig. 6. Fighting near the outflow of the Pechenihy reservoir of the Kharkiv region

Fig. 7. Destroyed dam part of the Pechenihy hydroelectric complex, Early October 2022. Photos taken from the Northern News Telegram channel

flooding of the banks of the Siverskyi Donets downstream, as a result of damage to the hydroelectric system, should have destroyed pontoon bridges and disrupted the logistics of the Armed Forces of Ukraine (AFU) [10].

In September 2022, the Armed Forces of Ukraine continued their counteroffensive on the Lyman-Yampil-Bilohorivka line. The Russians began attacking Ukrainian hydraulic infrastructure in the Kharkiv and Luhansk regions to hinder the advance of Ukrainian troops along the Siverskyi Donets River. ISW analysts suggested that the reasons for this were the destruction of pontoon bridges and other logistics routes of the Armed Forces of Ukraine on the Tetyanivka-Pryshyb-Lyman-Yampil line.

Based on this, the place of the Pechenihy reservoir in this local water conflict cannot be put into one category. The reservoir was clearly used by the Russian invaders as a "weapon". Even though the Pechenihy reservoir is an important source of water supply for many cities and communities in the Kharkiv region, the occupiers continued to attack this important hydraulic structure, fully understanding all the consequences of such attacks. At the same time, the reservoir was a "victim" that was not subjected to accidental shelling by the same Russian occupiers. The ambiguity of the classification can be traced in the following cause-and-effect relationship, which exhaustively describes the place of the Pechenihy reservoir in this water conflict: the reservoir was used by both sides of the conflict as a "lever of influence" in order to gain a strategic advantage during hostilities. During the retention of this "advantage" by one of the parties, the reservoir was sometimes subjected to shelling and assault attempts. The latter defines the Pechenihy reservoir as an unlawful victim. According to the classifications considered in the first section of the work, the water conflict under study can be characterized as follows:

- type of water fight: victim, weapon;
- type according to the level of exacerbation: local;
- type by form of conduct: armed;
- type by the nature of military activity nearby: explosions, mining, destruction.

The gradual deterioration of the technical component of the Pechenihy hydraulic structure coincided with the conduct of hostilities. In the previous paragraph, it was noted about the significant shallowing of the reservoir. It is worth dwelling on this in more detail, because such shallowing is a unique case in the history of the Pechenihy reservoir, and especially if we take into account the conditions that caused it. In the satellite images below, it is possible to visually track the increase in the coastline deep into the area of the reservoir (Fig. 8).

New "islands" formed in the reservoir that, under normal conditions, would not have existed. It is also possible to trace a kind of white outline around the entire plane of the reservoir. This is a coastline that has increased significantly due to a decrease in the water level. The threat of shallowing of a reservoir involved in water supply during hostilities can have serious negative consequences. A critical decrease in the water level in the reservoir could cause ecological degradation of the reservoir, disrupt the balance of the ecosystem and lead to the extinction of fish species and other aquatic organisms. More clearly the summer shallowing of the reservoir can be viewed in the pictures presented below (Fig. 9).

The Normalized Difference Moisture Index (NDMI) is often used to determine the moisture content of plants and monitor drought phenomena. This index, like no other, clearly shows the decrease in the water level from the shores of the reservoir under study. The range of NDMI values varies from -1 to 1. Negative NDMI values (from red and down the scale) correspond to the exposed land surface. Values close to zero (-0.032 to 0.032) are usually denoted as "water stress". That is, a decrease in the water level in our case, which usually shows droughts in the context of plants. High positive val-

(1)

(2)

Fig. 8. Satellite images of a part of the Pechenihy reservoir near the downstream are presented in a composite of natural colors (True Color). The (1) image is dated pre-war – 25.06.2021, respectively the second one (2) – 27.06.2022. Scale 1:20 000 [2]

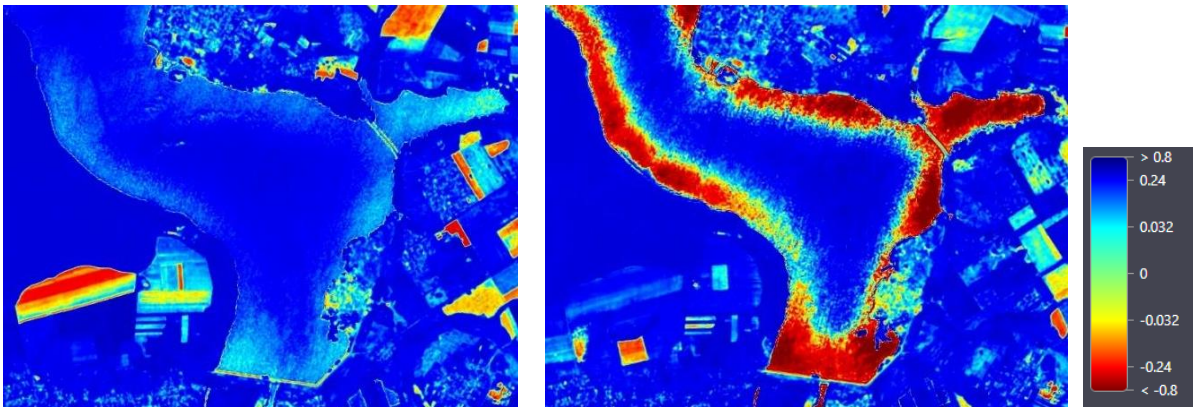

Fig. 9. Satellite images of the Pechenihy reservoir near the downstream are presented with a normalized difference moisture index (NDMI). The first image dates back to the pre-war time – 25.06.2021, respectively the second – 27.06.2022. Scale 1:20 000 [2]

ues correspond to high vegetation cover that is not subject to water stress (from 0.032 and up the scale).

By analyzing the obvious consequences of satellite images, it is possible to draw conclusions about their localization and better understand the stage of "drought" after damage to the locks. However, if we talk about the environmental assessment of the state of the reservoir under study, these consequences are less obvious and require a more thorough analysis.

Ecological condition of the Pechenihy reservoir. In order to determine the ecological state of the reservoir, general indicators of the composition and properties of surface waters obtained by the author during an internship at the Laboratory of Water and Soil Monitoring at the Regional Water Treatment Region of the Kharkiv region (Regional Office of Water Resources) were used. Indicators measured in early October 2022 and March 2023 were used to track the changes. October 2022 is characterized by

relative calm after the Kharkiv counteroffensive, and March 2023 is characterized by the absence of any hostilities near the reservoir under study. Among the analyzed indicators are: compounds of organogenic elements, namely ammonium-, nitrate-, nitrite, phosphate-ions (Table 1) and general indicators of the composition and properties of surface waters, including total nitrogen, biochemical oxygen consumption, dissolved oxygen, dry residue and chemical oxygen consumption (Table 2).

Table 1

Compounds of organogenic elements in the waters of the Pechenihy reservoir

Indicator, mg/dm3	Date of sampling		Maximum permissible concentration (MPC) value
	12.10.2022	15.03.2023	
Ammonium ions	0,50	0,40	0,20
Nitrate ions	1,20	1,60	50
Nitrite ions	0,13	0,05	0,10
Phosphate ions	0,54	0,55	0,10

Compounds of organogenic elements in water may indicate pollution of the aquatic environment due to anthropogenic activities. Usually, organogenic elements can get into the environment of water bodies from industrial emissions or, in our case, from military operations. Of these indicators, the value of the maximum permissible norms (MPC) exceeds the content of phosphate ions and ammonium ions. Compared to 2022, the content of nitrite ions in the water of the reservoir has significantly decreased, therefore, as of 2023, this compound does not exceed the maximum permissible concentration.

The excess of phosphate ions and ammonium ions can be explained by the contamination of the water surface with waste as a result of military activity nearby. Hostilities cause the destruction of infrastructure, such as water and sewage systems, or in our case, parts of a dam. This, in turn, can lead to uncontrolled leakage of wastewater, which contains large amounts of ammonium and phosphates, into the reservoir. Also, the probable cause of the excess of these substances may be fragments and remnants of spent equipment and exploded shells containing various chemicals that fall into the water during rains. Explosions can lead to the decay of various materials, including those that may be toxic or dangerous to water systems.

Table 2

General Indicators of Composition and Properties of Surface Waters

Indicator	Date of sampling		Maximum permissible concentration (MPC) value
	12.10.2022	15.03.2023	
Total nitrogen, mg/dm^3	0,68	0,67	10
Dry residue, mg/dm^3	550	600	500
Biochemical oxygen demand, mgO_2/dm^3	2,10	2,80	15
Chemical oxygen demand, mgO_2/dm^3	19,0	23,0	15
Dissolved oxygen, mgO_2/dm^3	8,0	8,8	9

General indicators of the composition and properties of surface waters help to assess the overall quality of a hydrological ecosystem. These indicators include variable parameters that characterize the physical, chemical and biological aspects of the aquatic environment. Of the above indicators, only the dry residue and chemical oxygen consumption significantly exceed the maximum permissible concentrations.

Exceeding the standards for the content of dry residue in the reservoir, especially in conditions when hostilities took place, may indicate water pollution. Dry residue includes solids that remain in the water after evaporation. Such substances may include mineral particles, waste, organic matter, and other solid materials. Particulate matter has a significant impact on aquatic ecosystems. Due to the excessive content of dry residue, the water transparency index can decrease, which in turn affects the light permeability for underwater plants and other organisms, and also, this excessive indicator can settle at the bottom, thereby changing the ecosystem environment of the reservoir. A sharp increase in the chemical consumption of oxygen in the water indicates a certain level of pollution of the reservoir and requires the implementation of measures to clean it. The COD value is an important characteristic of water, which allows us to draw conclusions about the

content of oxidized substances in water, but, unfortunately, does not provide any information about the composition of the pollutant [17].

The waters of the Pechenihy reservoir may also have similar indicators due to the transboundary nature of the Siverskyi Donets, as noted in the previous subparagraphs. Upstream is the Belgorod reservoir, whose water is moderately polluted. Therefore, a certain proportion of pollutants can enter the waters of the Pechenihy reservoir when water is discharged from the Belgorod reservoir upstream.

It should be noted that most of the general indicators of the composition and properties of surface waters do not exceed the maximum permissible concentrations and are within the normative values. This indicates that the ecological state of the Pechenihy reservoir is not so critical. Of course, if we talk about environmental performance. It is obvious that the consequences of the destruction of part of the hydraulic structure and shelling made certain adjustments to the hydro-ecological balance of the reservoir, but this impact cannot be called inevitable.

After the loss of the Oskil reservoir in the spring of 2022, the importance of the Pechenihy water reserve will increase. In addition, the studied reservoir is one of the cleanest in the region and covers significant needs with the water supply of Kharkiv. Therefore, the restoration of the Pechenihy hydroelectric complex to its former technical capabilities is important. However, before outlining the main directions of restoration, it is worth considering the current state of the reservoir under study. That is, the state of the Pechenihy reservoir at the beginning of April 2024. The main components for the characterization will be satellite images, thanks to which it is possible to clearly trace changes in the water level in the Pechenihy reservoir (Fig. 10).

The shoreline of the reservoir has significantly decreased, which indicates an increase in the water level. The islands that are sometimes visible on the surface of the reservoir in the summer 2022 image are no longer visible in the spring 2024 image. It can be said that two years after the cessation of hostilities, the Pechenihy reservoir regained its pre-war

(1)

(2)

Fig. 10. Satellite images are presented in a composite of natural colors (True Color) of a part of the Pechenihy reservoir near the downstream. The (1) image is dated 27.06.2022, respectively, the (2) one is dated 10.04.2024. Scale 1:20 000 [2]

boundaries (Fig. 11). Of course, some of the consequences of hostilities are still visible on the ground. It is these consequences that should be singled out for further restoration, because the conditional danger from the mining of territories, for example, threatens the environmental stability of the coastal regions of the reservoir under study.

Future prospects of the Pechenihy Hydraulic Structure. The primary area of restoration work should be a hydraulic structure. The restoration of dams after hostilities is a strategically important stage in the restoration of infrastructure and water management for sustainable development and security. As of November 2023, only three of the eight gateways are operational. As of April 2024, this situation has not changed, because the reconstruction of the dam to its former technical capabilities is not acute in today's conditions. It is enough to restore to the minimum possibilities. On the other hand, reducing the ability to regulate water levels by sluices can make the reservoir less resilient to extreme weather conditions. This can lead to an increase in the risk of floods or, conversely, a decrease in the water level to a critical state, as it was after the explosion.

As of April 2024, the water level in the reservoir is within the permissible limit. Confirmation of this can be seen in satellite images and photos above. The hydraulic structure on the downstream operates in a restrained mode. The technical condition of the hydroelectric complex does not allow us to guarantee that the dam will withstand the repetition of such explosions. The restoration of the dam is quite a complex process, especially when it is used as a transport link. However, the beginning of restoration work was laid, so in the near future the Pechenihy hydraulic structure may work in the mode in which it worked before the war.

(1)

(2)

Fig. 11. Photo of Pechenihy Reservoir for 27.06.2022 (1) and 10.04.2024 (2)

The Pechenihy reservoir was actively used for recreational purposes. However, now tourist activity around the reservoir is significantly limited due to the possible mining of the left-bank area, which was under occupation. When it comes to demining, first of all, the beginning of these works falls on ensuring the sustainability of land plots involved in agriculture, and, accordingly, the territories of settlements. Before the war, the left bank of the reservoir was a favorite vacation spot for many Kharkiv residents because of its clean beaches and a large number of recreation centers nearby. However, the resumption of tourism activities in the territory that still belongs to the areas with an active course of hostilities is not a priority aspect that requires urgent intervention. Therefore, a similar direction of restoration work should be noted for the future.

In general, it is worth talking about the full prospects for recovery after the end of hostilities. The Chuhuiv district is still considered an area with an active course of hostilities. Since the Pechenihy Hydroelectric Structure is a critical infrastructure facili-

ty, it will remain a target for enemy strikes until the end of the war.

Conclusions. As a result of the study, the following conclusions are raised:

1. The phenomenon of water conflicts is substantiated and its twofold manifestation is traced. Water clashes are not only negative processes in the geo-ecological aspect, but also a complex social phenomenon that has certain natural reasons for its occurrence. According to the generally defined classifications of «trigger», «victim» and «weapon», the place of water bodies in conflicts was considered and the indirect impact of hostilities on the formation of new foci of water clashes was traced on the example of the world and Ukraine as a whole. However, Military operations in the territories containing such facilities significantly exacerbate the problems that arose in peacetime and create significant man-made and hydroecological risks and conflicts that can completely destroy water bodies and adversely affect the environment.

2. The hydrological and technical characteristics of the direct object of study of this article are considered, which are very important, because before that they were not formed in this context. The data obtained from the Laboratory of the Regional Office of Water Resources in the Kharkiv region made it possible to identify the latest geo- and hydroecological problems of the Pechenihy reservoir and trace the gradual deterioration of its condition as a result of combat activity nearby.

3. The events of the local water conflict, which were collected by the authors of the work during the period of time from the beginning of the full-scale invasion of the Russian Armed Forces to the Kharkiv counteroffensive of the Armed Forces of Ukraine, are highlighted. For the first time, the Pechenihy Reservoir suffered significant damage as a result of hostilities, so such coverage of those events is relevant and new, because they are formed in the context of assessing the consequences of water conflicts.

4. Classification of the studied conflict was carried out according to the classifications of different researchers. This helped to determine that the local water conflict had dual classifications in terms of the role of water resources in it. In accordance with this, the water conflict around the Pechenihy reservoir is of an armed nature; the type of water skirmish, i.e. the place of water in the conflict – the victim, the weapon; type according to the level of exacerbation – local; type by the nature of military activity nearby – explosions, mining, destruction.

5. Potential ways of restoring the object of research are analyzed. Analysis and comparison of images of different times made it clear that the state of the Pechenihy reservoir is not critical when compared with other hydrological systems such as the Oskil or Kakhovka reservoirs. The greatest damage was caused to the technical part of the reservoir, namely the hydroelectric complex, so the lion's share of restoration work falls on it. It is worth talking about the full prospects for recovery after the end of the war.

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Прояви та наслідки водних конфліктів: на прикладі Печенізького водосховища, Харківська область Україна

Катерина Борисенко [1]
к. пед. н., доцент кафедри фізичної географії та картографії
[1] Харківського національного університету імені В. Н. Каразіна, Харків, Україна;
Саймон М. Хатчінсон [2]
PhD (географія), доцент факультету природничих наук, інженерії та навколишнього середовища
[2] Університету Солфорду, Солфорд, Велика Британія;
Діана Сінчук [1]
бакалавр кафедри фізичної географії та картографії

Водні об'єкти та можливість безперешкодного доступу до них є важливими ланками сталого розвитку будь-якого регіону. Моніторинг та аналіз стану водойм, що задіяні у водопостачанні населення та промисловості, є важливим етапом в уникненні майбутніх екологічних та гуманітарних катастроф. Особливо це важливо в умовах сьогодення України, коли виклики для водних об'єктів є суттєвими і являють собою не лише надмірне забруднення але й явища водних конфліктів, які в окремих випадках призводять до масштабних проблем. Водні конфлікти є серйозною проблемою у багатьох регіонах світу, де дефіцит водних ресурсів та їх нерівномірний розподіл призводять до соціально-економічної напруги та екологічних проблем. Виходячи з цього, подібні дослідження будуть актуальними допоки, доки в світі існують проблемні питання приурочені водопостачанню. В сучасних українських реаліях подібні дослідження слугують не лише науковими матеріалами, але й документальними свідченнями певних водних конфліктів, наслідки яких подекуди розцінюються як акт екоциду. Дослідження водних сутичок є важливим, а особливо в розрізі визначення його місця під час ведення збройних дій. Аналіз проявів та наслідків водних конфліктів, які створені внаслідок суперпозиції регіональних геоекологічних проблем регіону й активних і тривалих військових дій, які брутально проявилися у підривах гребель, на прикладі Печенізького водосховища має велике значення для розуміння механізмів виникнення конфліктів та їх впливу на різні аспекти життя регіону. Аналіз причин та наслідків водних конфліктів дозволяє розробити ефективні стратегії управління водними ресурсами, які можуть бути застосовані не лише на локальному, але й на національному та міжнародному рівнях. Печенізьке водосховище відіграє не останню роль у забезпеченні водними ресурсами навколишніх територій, підтримуючи біорізноманіття та сталість місцевих ландшафтів. Ця водойма подекуди є унікальною для Харківської області, бо є найчистішою в регіоні. Питання, що більш ґрунтовно розглядаються на прикладі Печенізького водосховища, є притаманними й деяким іншим еколого-гідрологічним об'єктам Лівобережного Лісостепу на межі з Північним Степом. Ці два зональні простори не мають чіткої межі, тому приналежні до них такі об'єкти варто розглядати спільно. Це Оскільське, Краснопавлівське, частково залишкова частина Каховської водойми, які постраждали внаслідок військових дій.

Ключові слова*: водні конфлікти, Печенізьке водосховище, бойові дії, гідрологічні ресурси, геоекологічний стан.*

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