AGORA International Journal of Economical Sciences, http://univagora.ro/jour/index.php/aijes
ISSN 2067-3310, E-ISSN 2067-7669
No. 1 (2023), pp. 70-82

PRINCIPLES OF WATER INFRASTRUCTURE MANAGEMENT IN ENSURING SUSTAINABLE WATER USE IN UKRAINE

N. MAHATS

Nataliia Mahats
State Organization «Institute of Market and Economic & Ecological Research of the National Academy of Sciences of Ukraine», Ukraine
https://orcid.org/0000-0003-0799-9462
E-mail: mahatsnataliia@gmail.com

Abstract. *The military actions in Ukraine significantly aggravate the problems of sustainable water resources management. Even in the pre-war period, the main funds of the drinking water supply and sanitation systems were characterized by an unsatisfactory technical condition, an extremely high percentage of wear and tear and required large capital investments. During the wartime, the water management infrastructure of Ukraine became the object of massive attacks by the Russian Federation, which led to catastrophic consequences, such as the destruction of critical infrastructure facilities, lack of population access to drinking water supply, contamination of drinking water sources, complications of the sanitary and epidemiological situation, which poses a significant threat to the health of the nation.*

The purpose of the article is to determine the current state, trends in the restoration and development of the water management infrastructure in Ukraine and the formation of the basic principles of its management to ensure sustainable water use in Ukraine. The methodological tools of the study were such approaches and methods as a systematic approach, methods of system-structural analysis and synthesis, comparison and generalization, economic and statistical methods.

Keywords: *Ukraine's water infrastructure, impact of the full-scale Russian invasion, sustainable water use principles, blue economy, circular economy, social responsibility*

INTRODUCTION

Water industry is an important component of any modern economy. Water facilities are crucial for the socio-economic development of Ukraine, as they provide centralized water supply and sanitation for the population, industrial and agricultural enterprises, as well as protect from negative consequences associated with water use. However, unfortunately, they can be subject to wear and tear and malfunction, which can lead to serious water quality problems, which in turn may affect public health and the state of the environment. This problem arises for a number of reasons, in particular, inadequate funding, inefficient management, lack of due attention to the protection and conservation of water resources. Modern management tools, such as smart water management, aimed at water infrastrustructure operation based on sustainability and self-sufficiency. It can be carried out through the use of innovative technologies, such as information and control technologies and monitoring. Thus, water management contributes to leakage reduction, water quality

assurance, improved customer engagement and operational optimization (Ramos et al., 2020).

The state of the water infrastructure has a significant impact on sustainable water use in the country. The European Union (EU) has implemented a series of directives aimed at ensuring the effective management of water resources and the preservation of water quality. These directives set out specific environmental requirements that water management facilities must adhere to in order to promote the sustainable use and protection of water bodies across EU member states. In the article (Bolognesi, 2014) it is examined main laws and regulations concerning water standards enacted at European level.

One of the main challenges for water infrastructure has always been the great quantity of electricity needed to extract, treat, convey and reuse water thus it becomes increasingly important to integrate renewable energy sources into water infrastructure systems. By harnessing renewable energy, it can be achieved a more sustainable and resilient water sector while mitigating the impacts of climate change. Bieber et al. (2018), using a scenario based approach, propose innovative water supply and energy deployment policies, which address the provision of clean energy for population and demonstrate the potential effects of climate change.

As long as water infrastructure systems in the developed countries evolved as products of the industrial revolution, design principles of that time were different. However, the existing water infrastructure design is incompatible with the present environmental, economic, and social principles of sustainability (Apul, 2010). Thus, it is necessary to implement modern principles of water infrastructure management, which will contribute to ensuring sustainable and efficient water resources use, meeting the population needs and preserving the environment.

I. Methodology

The methodology of this study was based on a combination of statistical analysis of the results of water infrastructure management in Ukraine in the pre-war 2020-2021 years, statistical and expert data on the impact of the of the Russian Federation on critical water infrastructure facilities in Ukraine, with an analytical study of modern principles of sustainable development that will affect the main directions of the post-war restoration of Ukrainian water infrastructure.

The study was conducted from November 2022 to April 2023 in the following stages:

1) collection of statistical information on the main indicators of the state of the centralized water supply and sanitation systems in the regions of Ukraine in 2020-2021;

2) analysis of recent reports and studies on the impact of the Russian full-scale military aggression in Ukraine in terms of determining the damage caused to Ukraine's water resources and water infrastructure;

3) determination of the main principles of sustainable development in the context of the conceptual foundations of the circular economy, social responsibility, blue growth and the possible vectors of its application for the post-war restoration of Ukraine's water infrastructure.

The study was based on such information resources as the statistical-analytical report of the World Bank, statistical data report of UNICEF, statistical data of the Ministry for Communities and Territories Development of Ukraine, publications of Ukrainian and foreign

scientists on the research topic according to the list of references (22). The following approaches and methods served as the methodological tools of the study: a systematic approach, methods of system-structural analysis and synthesis, comparison and generalization of a systematic search, economic-statistical methods.

I.1. The analysis of the pre-war problems in the field of water management and the current state of the water infrastructure in Ukraine

The water infrastructure of Ukraine consists of a large number of structures and objects, such as water intake facilities, water pressure towers, water supply and sanitation networks, treatment and hydrotechnical facilities, reservoirs, etc. Before the war, the main funds of water industry of Ukraine were mostly characterized by an unsatisfactory technical condition, since they were built in the 60s of the last century, they needed serious capital repair and in some cases complete reconstruction.

According to the Ministry for Communities and Territories Development of Ukraine (MinRegion, 2021), in 2020 the total length of water supply networks was 121921 km, including dilapidated and emergency networks – 46602 (38%); during the year, 991 km (2,1%) of the need were renewed. The total length of centralized sanitation networks was 46602 km, including dilapidated and emergency – 16618 km (35,6%); during the year, 186 km (1,1%) of the need were renewed. As can be seen from fig. 1 the rate of renewal of the water supply and sewerage network in Ukraine is quite low and does not meet the needs of the population and the economy.

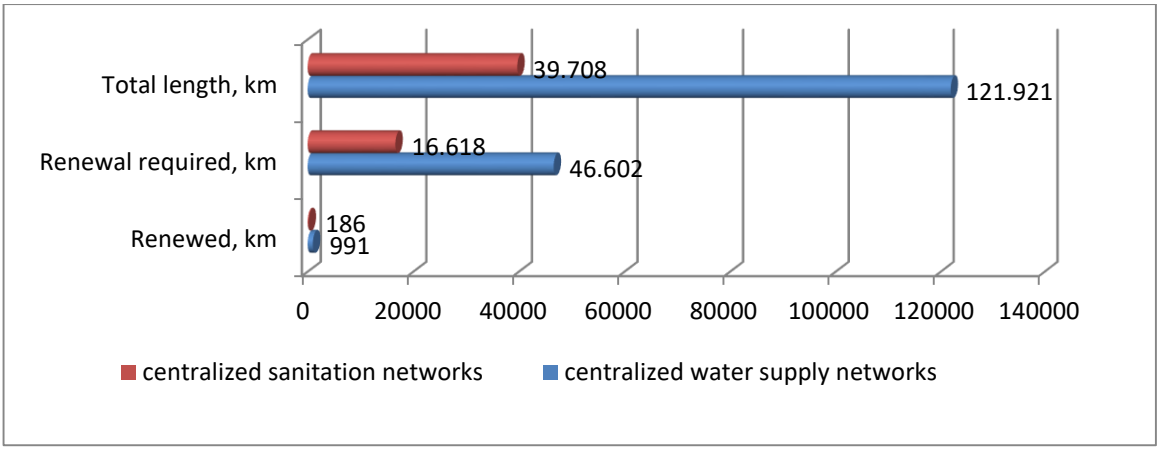

Fig. 1. The length and condition of centralized water supply and sanitation networks in Ukraine in 2020.

Source: compiled by the author based on (Ministry for Communities and Territories Development of Ukraine [MinRegion], 2021)

Another indicator of the state of the water infrastructure in Ukraine is the accident rate of centralized water supply and sanitation networks, which can be caused by various factors, in particular, such as aging networks, insufficient funding, negligence in operation, etc.

Accidents on water supply and sanitation networks can lead to interruptions in the supply of drinking water, its pollution, flooding of territories, environmental pollution and pose a threat to human health.

So, in 2020, the average accident rate of the centralized water supply network in the regions of Ukraine amounted to 1,83 accidents per 1 km of the network, in particular, the largest number of accidents was in the Kiev region – 6,38 accidents and in Odessa – 4,92 accidents per 1 km of centralized water supply network; the lowest – in the Cherkasy region – 0,04. The average accident rate of the centralized sanitation network in the regions of Ukraine amounted to 1,54 accidents per 1 km of the network, the largest number of accidents was in the Kyiv region – 6,0 accidents and Kharkiv – 4,3 accidents per 1 km of the centralized sanitation network; the lowest – in the Kirovohrad region – 0,09 (Fig. 2).

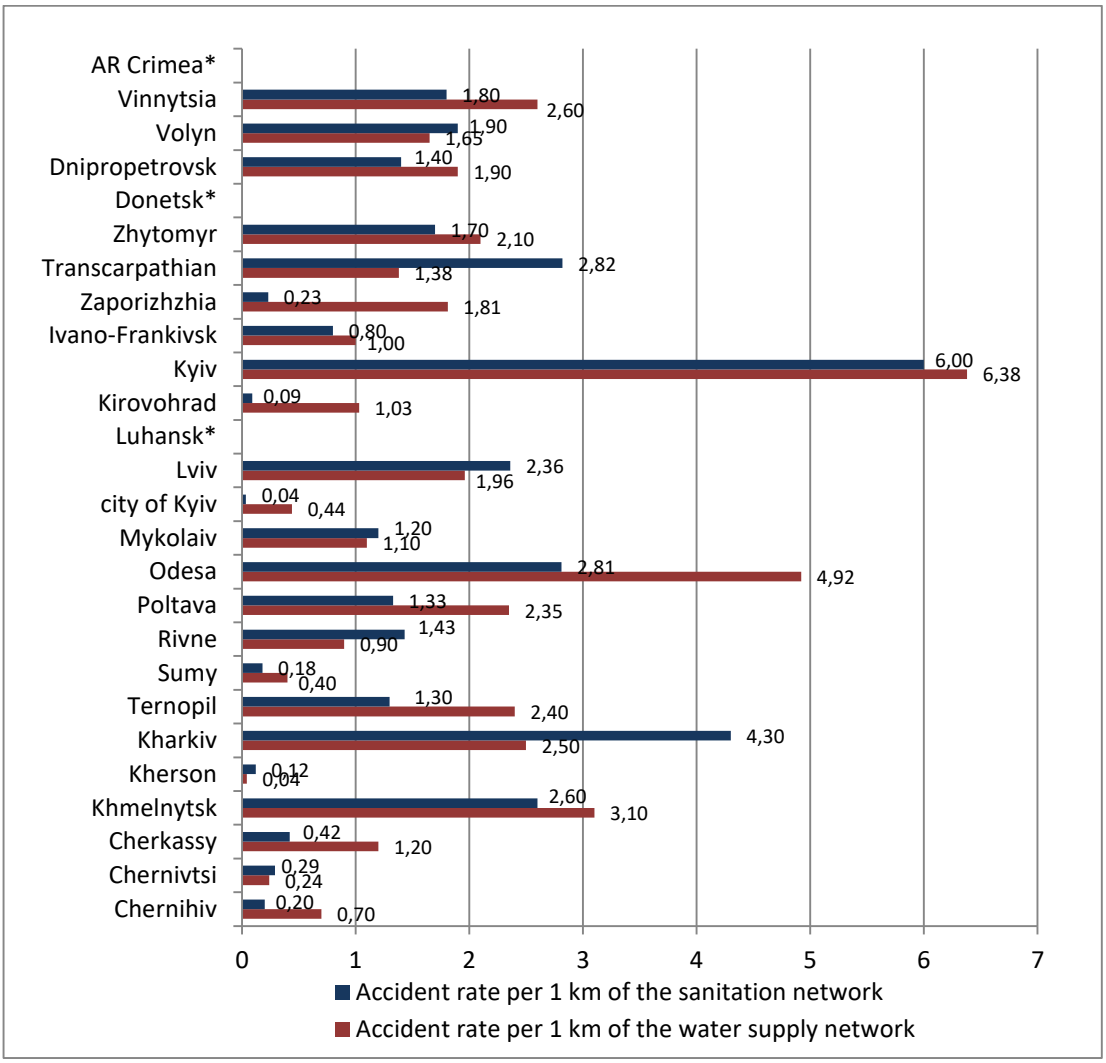

Fig. 2. Accident rate of centralized water supply and sanitation networks in Ukraine in 2020
* the statistical information was not available in the temporarily occupied territories
Source: developed by the author based on data (MinRegion, 2021)

In rural areas of Ukraine, in particular in the east and west of the country, the water infrastructure was less developed and had a low level of technical equipment. According to (MinRegion, 2022), in 2020-2021, more than 75% of rural areas in Ukraine did not have access to centralized water supply and sanitation systems (Table 1).

Table.1. Provision of settlements in Ukraine with centralized water supply and sanitation systems in 2020-2021

Year	Cities			Urban type settlements			Rural settlements		
	Total	Provided with	%	Total	Provided with	%	Total	Provided with	%
centralized water supply									
2020	314	310	98,7%	473	432	91,3%	22 204	5 382	24,2%
2021	314	310	98,7%	473	427	90,3%	22 204	5 215	23,5%
Centralized sanitation									
2020	314	301	95,8%	473	319	67,4%	22 204	323	1,45%
2021	314	301	95,8%	473	319	67,4%	22 204	330	1,48%

Source: grouped by the author based on data (MinRegion, 2022)

According to the tasks specified in the National Report "Sustainable Development Goals: Ukraine"(2017), the share of the rural population with access to centralized water supply should increase from 17,2% in 2015 to 80% in 2030; the share of the rural population with access to improved sanitation should increase from 1,9% in 2015 to 80% in 2030, which is quite an ambitious target even in peacetime.

Thus, in 2021, only 23,5% of rural settlements in Ukraine had access to centralized water supply and 1,45% to centralized sanitation. These circumstances can lead to the use of low-quality water from open sources such as rivers and ponds, which can subsequently cause the spread of diseases and threaten the health of the local population. In addition, the lack of sanitation systems can lead to environmental pollution, in particular water resources and soil.

To solve the problems of providing rural settlements of Ukraine with centralized water supply and sanitation systems, it is necessary to apply an integrated approach. In particular, according to professors M. Khvesik and V. Golyan (2014), the priority areas for the modernization of the water infrastructure in rural areas should be: increasing the volume of work on the construction of new and reconstruction of existing centralized water supply and sanitation systems in rural settlements; technical and technological restructuring of inter-farm and intra-farm networks of hydraulic structures; construction of those water infrastructure facilities that will contribute to the implementation of the European Union directives. In a study by N. Kovshun (2015) it is noted that a perspective economic mechanism for financing the water infrastructure of Ukraine is a public-private partnership, when the state, to solve a specific problem for a water facility, involves private initiatives.

Solving the problematic issues of the water infrastructure functioning can improve the living conditions of the rural population and provide a more sustainable future for rural development in Ukraine.

I.2. The impact of the full-scale military aggression of the Russian Federation on critical water infrastructure facilities in Ukraine

The full-scale military aggression of the Russian Federation has a serious impact on water resources and water security both at the national and global levels. Although, according to the Geneva Conventions (1949), countries involved in armed conflicts are obliged to observe and ensure compliance with international humanitarian law under any circumstances. However, there is a global trend towards increasing the use of water resources and infrastructure as a target or means of warfare in armed conflicts. The full-scale Russian invasion and intense hostilities in Ukraine led to the destruction of critical infrastructure, including water industry facilities.

In the study (Shumilova et al., 2023), the authors examined how military operations affected water resources and water management infrastructure during the first three months of the war. A total of 64 reported impacts on the water sector were investigated, in particular, such as interruption of water supply; disruption of sanitation networks and treatment facilities; pollution of surface waters due to the release of chemicals as a result of shelling and bacteriological contamination due to mass death of poultry; damage to dams; mine flooding; disruption of a hydroelectric power plant.

The article (Gopchak et al., 2022) provides methodological recommendations for calculating the damage from the destruction to fixed assets of the water sector for industrial and non-industrial purposes, and calculating the costs of restoring the infrastructure. In particular, it was noted that the volume of damage to active war zones will increase linearly over time at a rate of 0.274% per day. If the region is under occupation, the growth rate of damage is 0.137% per day.

In the World Bank report (2022), it is noted that the most affected water infrastructure facilities were water supply and sanitation networks, water treatment facilities, drinking water treatment plants. Table 2 shows the water infrastructure facilities, their damage and estimated needs for reconstruction. The information provided is not exhaustive given the difficulty of obtaining data from temporarily non-government controlled areas.

Table.2. Water infrastructure damage inventory and estimated recovery and reconstruction needs as of June 2022

Object type	Type of damage			Reconstruction needs, USD million		
	Partially damaged	Completely destroyed	Total	Urgent / short-term	Medium- to long-term	Total
Water treatment facilities (units)	8	2	10	39,0	156,0	195,0
Wastewater treatment facilities (units)	10	4	14	72,0	288,0	360,0
Water pumping stations (units)	20	18	38	13,7	54,6	68,3
Sewage pumping stations (units)	32	19	41	28,6	114,5	143,1

Water supply networks (km)	0	816,314	816,314	122,4	489,8	612,2
Sanitation networks (km)	0	241,665	241,665	108,7	435,0	543,7
Wells (units)	11	13	24	0,6	2,4	3,0
Laboratories (units)	3	2	5	0,3	1,2	1,4
Clean water tanks (units)	4	12	16	4,1	16,3	20,4
Water towers (units)	8	24	32	1,6	6,5	8,2
Total, USD million				391,0	1564,3	1955,3

Source: compiled by the author based on data (World Bank, 2022)

Water infrastructure recovery and reconstruction needs are based on damage and losses as of June 2022. At that time, they were estimated at about USD 1,955 million. Partially damaged and destroyed infrastructure requires restoration on a priority basis. The necessary investments are divided into urgent - short-term (USD 391,0 million) and medium-long-term (USD 1564,3 million). The needs assessment considers a "build back better" approach to recovering damaged/destroyed water infrastructure objects.

The Bulletin of the Observatory of Conflicts and the Environment (2022) analyzes the impact of the war on the state of the water supply sector and on the water resources of Ukraine, in particular, it is studied the most devastating incidents for the period February-August 2022, such as the explosion of the dam of the Kakhovskaya hydroelectric power station, damage to the Mykolaiv pipeline, numerous accidents with damage to the pumping stations of the water supply system in the city of Popasna and the Severskyi Donets canal, the destruction of the Irpen dam, which led to flooding.

However, the greatest destruction Ukraine's critical infrastructure has experienced since October 2022, when the Russian Federation launched massive and methodical missile strikes throughout Ukraine approximately every 10 days, in particular, water supply networks, sewerage systems and other water infrastructure facilities were damaged. In general, for the period October 2022 - March 2023, the Russian Federation launched 908 missiles and 95 kamikaze drones in order to destroy critical infrastructure. As a result, according to UNICEF (2022), as of December 2022, 16 million Ukrainians had limited access to water, sanitation and hygiene. The situation is especially critical in the east and south of Ukraine, where people are forced to fight for access to water supply and sanitation services in order to meet their vital needs.

The energy crisis in December 2022 – February 2023 further aggravated the problems: power outages affected the condition of water pumping stations and led to interruptions in water supply throughout Ukraine. Internally displaced persons in collective centers and host communities faced significant restrictions in access to water, hygiene and sanitation.

Restoration of water infrastructure facilities during the active phase of hostilities is an extremely difficult, but also the most important task for ensuring the safety and health of the

population under martial law. The main obstacles to the timely resumption of the water infrastructure facilities functioning are:

- location of damaged objects in the occupied territory;
- location of damaged objects in the zone of active hostilities and shelling.

However, in other territories of Ukraine, updating water infrastructure facilities to an adequate technical condition is not a priority task for local authorities in wartime.

II. Results – Principles of post-war reconstruction and management of Ukrainian water infrastructure on the basis of sustainable development

The destruction of Ukraine's water infrastructure leads to serious consequences for public health, in particular, to a decrease in the quality of drinking water and an increase in the risk of epidemics and other diseases that are transmitted through water. In addition, as a result of missile attacks, mining, especially in the zone of active hostilities, there is a lot of toxic explosive material that can pollute water sources and lead to the destruction of aquatic and semi-aquatic ecosystems.

In the post-war period, Ukraine will face many challenges in the field of water management. Therefore, today, when forming a strategy for the post-war development of Ukraine, it is necessary to take into account modern principles of water infrastructure management, which should be based on the main provisions of the circular economy, social responsibility, blue growth (Fig. 3) and promote sustainable water use and conservation of water resources for future generations.

Management of water infrastructure according to the principles of the circular economy implies an increase in the efficiency of the use of water resources and a reduction in waste from the water sector. The 10R principles, developed by J. Cramer (2017), are the basis for the introduction of a circular economy and can be applied in the water management sector to ensure the sustainable water use.

Refuse and reduce: reducing water consumption by eliminating inefficient water use, applying water-saving technologies and changing consumer behavior.

Redesign, Repair, Refurbish and Remanufacture – these are important circular economy principles that can be applied to water supply and sanitation management to promote the sustainable and efficient use of water resources. For example, designing water systems that collect and use rainwater while reducing the amount of water needed from other sources; repairing leaking pipes and refurbishing wastewater treatment plants with more advanced treatment technologies; reconstruction of the existing water management infrastructure to extend its service life.

Reuse, Re-purpose, Recycle, Recover – include recycle of treated wastewater for non-potable needs such as irrigation, industrial processes, domestic needs, etc.; reuse of storm water for non-potable purposes such as industrial cooling or landscaping; recover of valuable resources from wastewater for use in agriculture or bioenergy production. The application of wastewater reclaiming and recycling practices is discussed in more details by the author in the preliminary study (Khumarova & Mahats, 2022).

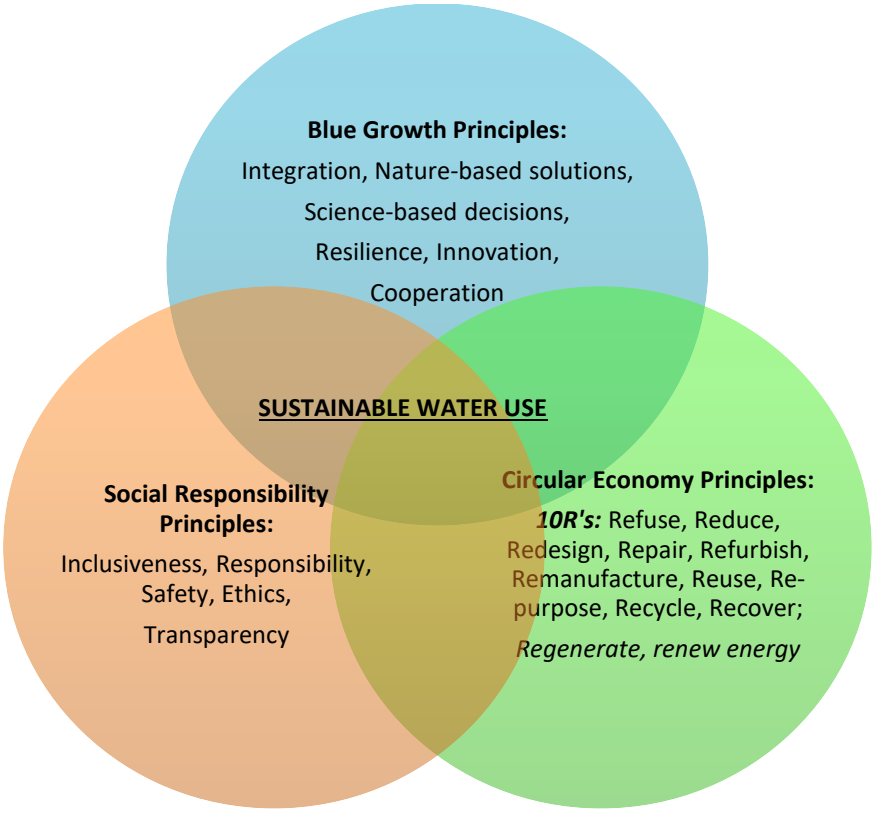

Fig. 3. Interrelation of circular economy, blue growth and social responsibility principles in ensuring sustainable water use

Source: developed by the author

Having considered the main 10R principles of the circular economy, it is proposed to pay attention to such important principles of water infrastructure management as:

Regenerate – means restoring natural ecosystems and water resources to a healthy and productive state. Regenerative practices can help reduce pollution, improve water quality, and promote biodiversity conservation.

Renew energy. The use of renewable energy sources can be a valuable tool for managing water infrastructure. Using renewable energy sources to power water infrastructure can reduce energy consumption, reduce carbon emissions and promote sustainable development. Thus, the use of renewable energy sources can include solar-powered water treatment, the use of wind energy to power pumps for transporting water through pipelines, the production of biogas from the treatment of wastewater sludge, etc.

By applying these principles to the water sector, businesses and societies can improve water use efficiency, reduce waste, and promote sustainable water infrastructure management practices.

Blue growth as part of the sustainable development concept involves using the potential of marine and coastal regions for balanced development in economic, social and environmental aspects. This approach recognizes the importance of water as a critical resource for economic development and takes into account the needs of rational use to ensure the availability of water for future generations. Based on the main provisions of the book by G. Pauli (2010), it is identified the following principles and tools for blue growth in water

management (Table 3). The application of blue growth principles will contribute to the sustainable use of water resources, the conservation and restoration of aquatic ecosystems and the reduction of the human activity impact on the environment.

Table 3. Blue growth principles and instruments in water infrastructure management

Principle	Meaning	Implementation Tool
Integration	ensuring interconnection between various sectors, such as water supply, sanitation, environmental protection, energy and transport, in order to achieve a common goal – the efficient and sustainable use of water resources.	• integrated water management plan; • integrated environmental permit.
Nature-based solutions	taking into account natural processes and environmental factors in the planning and construction of water management infrastructure, in particular, in the construction of reservoirs, sewage networks, dams, etc.	• environmental impact assessment; • the concept of "green infrastructure"; • ecosystem approach.
Science-based decisions	use of scientific research and expert assessments for decision-making regarding the use of water resources and the management of water infrastructure.	• data analysis and forecasting; • monitoring and control; • modeling; • expert systems.
Resilience	the ability of water infrastructure management to maintain its performance and adapt to changes in the ecological, economic and social environment.	• risk and vulnerability assessment of water management systems; • development a contingency plan; • development of strategies for rapid reaction to changes.
Innovation	application of the latest technologies and innovative solutions to improve the efficiency and sustainability of the water infrastructure.	• digital technologies; • renewable energy sources; • modern construction materials and technologies.
Cooperation	provides for interconnection between various parties, including governmental and non-governmental organizations, public organizations, scientists, business and society to achieve the sustainable use of water resources.	• public consultations; • involvement of stakeholders in the planning and decision-making process; • creation of platforms for information exchange and actions coordination.

Source: developed by the author

Water infrastructure management based on the provisions of social responsibility implies an understanding of the water industry enterprises impact on society and the natural environment and a responsible attitude towards the consequences of this impact. This means that water management must respond to the needs of the public, ensure that services are accessible to all groups of the population, contribute to positive changes in society and prioritize environmental practices. Sharing the vision of O. Grishnova (2011) on understanding the essence of social responsibility, it is formed some of the most important principles, including:

Inclusiveness: ensuring equity in access to water resources for everyone, regardless of social status and other characteristics. This can be achieved by introducing programs and projects that help improve access to water and sanitation for all people, especially those who are in a vulnerable state.

Responsibility: management of the water infrastructure in accordance with the laws, rules and regulations relating to the water sector, and responsibility for the consequences of the use of water resources and water infrastructure.

Safety: provides for high-quality drinking water supply to the population, the proper technical condition of the infrastructure, as well as safe working conditions for employees of water industry organizations.

Ethics: upholding high standards of virtue and morality in the decision-making process of water infrastructure management. This means that decision-making should be based on objective facts and analysis, and not on personal interests or corruption.

Transparency: providing access to information on the state of water resources and water infrastructure, the decision-making process and the activities of management bodies through open data and reports.

In previous studies of the author (Khumarova & Mahats, 2023), it was substantiated that the organization of water management on the basis of social responsibility will help ensure the harmonious development of the economy and the social sphere and will improve the quality of life of the population.

CONCLUSIONS

After the end of the war, the restoration and development of water management infrastructure is one of the most important tasks for the economic recovery and the socio-economic development of territories that have been destroyed as a result of military operations. After analyzing the general pre-war problems in the field of water management and the current state of the water infrastructure in Ukraine, it was determined that in order to ensure sustainable water use in Ukraine, the management of water infrastructure should be based on the basic principles of the circular economy, blue growth and social responsibility. At the same time, achieving sustainable water use in Ukraine requires cooperation and coordination of actions of all stakeholders, including state authorities, public organizations, scientific and research institutions, the private sector and society (Carius et al., 2004).

Until the end of hostilities and the complete de-occupation of the entire territory of Ukraine, it is very difficult to assess the scale of the water infrastructure destruction and make suggestions on further trends in their restoration. However, based on today's global

initiatives, the basic principles of sustainable development and the “build back better”, it is possible to propose the main vectors for the subsequent post-war recovery and development of Ukraine's water infrastructure (Kitowski et al., 2023):

- restoration and modernization of water management facilities, considering the environmental requirements of the European Union directives;
- expansion of the centralized water supply and sanitation network, especially in rural areas;
- reducing the share of traditional energy sources in the supply of water infrastructure and increasing the use of renewable energy sources;
- equipping water infrastructure facilities with innovative technologies and introducing "smart" water management systems;
- designing new water supply and sanitation systems, considering the introduction of water recycling practices.

Thus, introducing these main vectors of water infrastructure development should ensure the efficient use of water resources, social justice, environmental conservation and sustainable economic growth.

REFERENCES

1. Apul, D. (2010). Ecological design principles and their implications on water infrastructure engineering. *Journal of Green Building*, 5 (3), 147–164. https://doi.org/10.3992/jgb.5.3.147
2. Bieber, N., Ho Ker, J., Wang, X. et al. (2018). Sustainable planning of the energy-water-food nexus using decision making tools. *Energy Policy*, 113, 584-607. https://doi.org/10.1016/j.enpol.2017.11.037
3. Bolognesi, T. (2014). The paradox of the modernisation of urban water systems inEurope: Intrinsic institutional limits for sustainability. *Natural Resources Forum*, 38(4), 270-281. https://doi.org/10.1111/1477-8947.12052
4. Bulletin of the Observatory of Conflicts and the Environment. (2022). *Ukraine conflict environmental briefing*. https://ceobs.org/ukraine-conflict-environmental-briefing-water/
5. Carius, A., Dabelko, G.D., & Wolf, A.T. (2004). Water, conflict, and cooperation. *Environmental Change and Security Project Report*, 10, 60-66.
6. Cramer, J. (2017). The raw materials transition in the amsterdam metropolitan area: added value for the economy. *Well-Being and the Environment*, 59, 3, 14-21. https://doi.org/10.1080/00139157.2017.1301167
7. Gopchak, I., Kovalov, I., Zhuk V. et al. (2022). Determination of damage caused to hydro-economic infrastructure facilities as a result of the armed aggression of the russian federation against Ukraine. *Scientific Bulletin Of Civil Engineering*, 108, 2. https://doi.org/10.29295/2311-7257-2022-108-2-60-67
8. Grishnova, O. (2011). Social responsibility in the context of overcoming the systemic crisis in Ukraine. *Demography and social economy*, 1(15), 39-46. https://doi.org/10.15407/dse2011.01.039
9. International Committee of the Red Cross. (1949). *Geneva Convention Relative to the Protection of Civilian Persons in Time of War*. https://www.refworld.org/docid/3ae6b36d2.html
10. Kitowski, I., Sujak A., & Drygaś M. (2023). The water dimensions of Russian –

Ukrainian Conflict. *Ecohydrology & Hydrobiology*. https://doi.org/10.1016/j.ecohyd.2023.05.001.

11. Khumarova, N., & Mahats, N. (2023). Implementation of the conceptual principles of business social responsibility in ensuring rational water use. *Economic Forum*, 1(1), 8-17. https://doi.org/10.36910/6775-2308-8559-2023-1-2
12. Khumarova, N.,& Mahats, N. (2022). Wastewater reclaiming and recycling: essence and directions for implementation. *Economic Innovations*. 24, 2(83), 195-204. https://doi.org/10.31520/ei.2022.24.2(83).195-204
13. Khvesyk, M., & Golyan, V. (2014). Modernization of water infrastructure as a factor in accelerating the socio-economic development of rural areas. *The Economy of Agro-Industrial Complex*, 7, 121-126. http://eapk.org.ua/sites/default/files/eapk/14_07_121-126.pdf
14. Kovshun, N. (2015). Financing of the water management complex: mechanisms, trends and prospects. *Mechanism of Economic Regulation*, 4, 118–126. https://mer.fem.sumdu.edu.ua/content/acticles/issue_27/NATALIA_E_KOVSHUNFinancing_Water_Complex_Mechanisms_Trends_and_Perspective.pdf
15. Ministry for Communities and Territories Development of Ukraine. (2021). *National report on the quality of drinking water and the state of drinking water supply in Ukraine in 2020.* https://www.minregion.gov.ua/wp-content/uploads/2021/12/naczionalna-dopovid-pro-yakist-pytnoyi-vody-ta-stan-pytnogo-vodopostachannya-v-ukrayini-u-2020-roczi.pdf
16. Ministry for Communities and Territories Development of Ukraine. (2022). *National report on the quality of drinking water and the state of drinking water supply in Ukraine in 2021.* https://www.minregion.gov.ua/wp-content/uploads/2022/12/naczionalna-dopovid-pro-yakist-pytnoyi-vody-ta-stan-pytnogo-vodopostachannya-v-ukrayini-u-2021-roczi.pdf
17. Ministry for Development of Economy and Trade of Ukraine. (2017). *National report "Sustainable Development Goals: Ukraine".* https://www.kmu.gov.ua/storage/app/sites/1/natsionalna-dopovid-csr-Ukrainy.pdf
18. Pauli, G.A. (2010). *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs*. Paradigm Publications.
19. Ramos, H.M., McNabola, A., López-Jiménez, P.A., Pérez-Sánchez, M. (2020). Smart water management towards future water sustainable networks. *Water*, 12(1), 58. https://doi.org/10.3390/w12010058
20. Shumilova, O., Tockner, K., Sukhodolov, A. et al. (2023). Impact of the Russia–Ukraine armed conflict on water resources and water infrastructure. *Nature Sustainability.* https://doi.org/10.1038/s41893-023-01068-x
21. UNICEF. (2022). *Ukraine Country Office Humanitarian Situation Report No. 24.* https://www.unicef.org/ukraine/media/29836/file/Ukraine-Humanitarian-SitRep-December-2022.pdf
22. World Bank, Government of Ukraine, European Commission. (2022). *The Ukraine Rapid Damage and Needs Assessment.* https://www.minregion.gov.ua/wp-content/uploads/2022/09/ukraine-rdna_report_print.pdf