ENVIRONMENTAL PROBLEMS

Vol. 10, No. 4, 2025

MONITORING AND REVITALIZATION TECHNOLOGIES OF DNIPRO RESERVOIRS

Olena Stepova, Svitlana Shara

National University "Yuri Kondratyuk Poltava Polytechnic",
24, Pershotravneviy Ave., Poltava, 36011, Ukraine
sv.shara12@gmail.com

https://doi.org/10.23939/ep2025.04.319

Received: 04.08.2025

Abstract. The uneven distribution of water resources in the territory of Ukraine caused the need for water storage of the surface watercourse of the Dnipro and the creation of six hydraulic nodes. However, the erosion of the shores, the sediments of the falling rivers, and the chemical pollution of the waters have led to ecological phenomena that indicate that artificial reservoirs cannot exist without constant work and reconstruction. Therefore, it is proposed to build embankment and washing islands that deepen the bottom of the reservoir to complete the shore fortifications, that is, carry out the revitalization of the Kremenchuk Reservoir.

Keywords: coastal erosion, reservoir filling, restoration technologies, reservoir monitoring, national program.

1. Introduction

Humanity's intervention in natural resources, the formation of anthropogenic landscapes, the need to maintain the necessary conditions of agro landscapes and preventing a return to the state of natural chaos and entropy of the biosphere requires scientifically based and reasonable systemic approaches, both in individual local ele-ments of natural complexes and in general on a planetary scale.

The situation will only worsen if you do not influence the artificially created object. A particularly critical condition is emerging at the Kremenchuk Reservoir, with an area of 225.4 thousand hectares (13.5 million m^3).

Thus, the reservoir's shoreline length within the Cherkasy region is 543.7 km, and the shores subject to erosion are 122.7 km long. Within the Poltava region, the total length of the coastline subject to erosion is 43.9 km. Therefore, losses of arable land due to the reclamation of the coastline amounted to 2.000 ha only in these are-as.

Annual siltation of reservoirs ranges from 0.5 to 2 cm, and shallow water (less than 2 meters deep) has reached an area of 132 thousand hectares. Therefore, the fairway must be deepened in three places of the navigable part of the Dnieper.

Society and the state faced an urgent problem of preserving and restoring the ecological balance in nature, as well as the complex rational use of artificially formed water bodies and territories. The national target program for developing water management and environmental improvement of the Dnipro River basin until 2021 (Law of Ukraine, No. 4836-VI, 2013) has not been implemented. The article identifies the problems of an ecologically dangerous situation around the Kremenchuk Reservoir and identifies ways and technologies to improve the situation. Reservoirs cannot exist in conditions of self-regulation because they are artificial structures and must be constantly maintained in an ecologically stable state. Over the years, the state of artificial reservoirs has deteriorated, so it is necessary to comprehensively investigate the factors that negatively affect the flora and fauna of reservoirs and their parameters. Directions for the ecological revitalization of the Dnipro basin, particularly the Kremenchuk Reservoir,

For citation: Stepova, O., Shara, S. (2025). Monitoring and revitalization technologies of Dnipro Reservoirs. *Journal Environmental Problems*, *10*(4), 319–324. DOI: https://doi.org/10.23939/ep2025.04.319

are proposed. The foreign experience of restoring ecosystems due to water accumulation in wetland complexes, groundwater, forests, meadows, soil, lakes, rivers, and streams was analyzed (Bashlyk, 2017; Vermaat et al., 2005). The necessity of land restoration, afforestation, and urbanization of the shallow parts of the Dnipro reservoirs has been determined where it is proposed to build alluvial and embankment peninsulas and islands, canals, which will make it possible by deepening the bottom of the Kremenchuk Reservoir, to significantly improve the ecological condition of the waters and return thousands of hectares of reclaimed land to economic use.

2. Materials and Methods

During the study, the scientists analyzed and proposed to envisage carrying out a complex of works and con-crete measures for the revitalization of the reservoir, both at the Dnipro water nodes and at tributaries, reservoirs, ponds and adjacent territories.

2.1. Review of sources

The uneven distribution of water resources in the territory of Ukraine necessitated the creation of a network of reservoirs – artificial reservoirs to regulate the flow and accumulation of water and its further use for economic purposes. As a result, there are more than fifty reservoirs in Ukraine, including cascade reservoirs on the river Dnipro: Dniprovske (water mirror area 410 km^2), Kamianske (567 km^2), Kanivske (582 km^2), Kyivske (922 km^2), Kakhovske (2155 km^2), Kremenchutske (2250 km^2).

The positive impact of reservoirs on economic activity since the end of the 50s of the last century (creation of cascades of hydroelectric power plants, improvement of conditions for river transport, irrigation of agricultural lands, breeding of fish and waterfowl, design of territories for recreation, etc.), in recent years, has turned into the emerging environmental problems, in particular coastal erosion, increasing the area of shallow water bodies, siltation, bloom and water pollution, etc., in case of excessive anthropogenic load on reservoirs in the absence of capital investments in improving the infrastructure of reservoir operation, and in case of non-compliance of reservoir management with the principles of sustainable development.

Studies of the history and consequences of hydraulic construction on the Dnieper indicate significant destruction of traditional settlement structures of Ukrainian villages and valuable historical monuments and ecological damage to nature due to large-scale flooding of territories (Belenok et al., 2017). Therefore, cartographic materials are essential in visualizing information about flooded parts. Especially valuable is mapping with the designation of individual flooded settlements (Dovhyi et al., 2020).

Studies of the current state of reservoir use are mainly related to ecological monitoring, which concerns the overgrowth of reservoirs, flowering, and water pollution (Hlotov et al., 2010; Dovhyi et al., 2020; Nesterenko et al., 2025), as well as the problems of reservoir operation and management (Khilchevskyi, 2017). At the same time, the technologies of geoinformation systems and methods of remote sensing of the Earth are widely used (Khortytsia National Reserve, 2022). Thus, the integration and interconnection of heterogeneous datasets – including satellite observations, ground-based measurements, laboratory analyses, and records from hydrometeorological posts and stations – remains a highly relevant aspect of contemporary environmental research.

In Ukraine, works to improve the state of reservoirs are carried out in small volumes. According to information sources (Old Dnieper, 2022) the Kremenchuk Reservoir advances on the banks by an average of 2 to 8 m annually. As a result of the intensive collapse of the reservoir banks, new shallow waters are formed. At high air temperatures, natural and artificial processes occur, causing water pollution. There is also a threat of flooding in some settlements. Globally, most restoration efforts have been concentrated on river revitalization and the removal of dams, ponds, and reservoirs. Yet, due to the relatively recent formation of large-scale water storage systems, there is still insufficient empirical evidence to fully evaluate long-term approaches to their ecological revitalization. Therefore, the situation around the Kremenchuk Reservoir, like most other Dnipro Reservoirs, requires a set of measures to restore the ecological state of the reservoirs and rational use of coastal areas. In practice, the term “revitalization” is often used for this purpose, which in translation from Latin means “return of life” (Vyshnevskyi, 2018). It is used in scientific and practical activities to characterize the processes of recovery, revitalization, and reproduction. Regeneration in hydrology involves, first, the ecological restoration of water bodies, that is, the maximum preservation of the natural factors of the existence of the water ecosystem. For example, the revitalization of rivers involves

abandoning the straightening of the river, constructing coastal areas, and con-creting of banks and is aimed at clearing the riverbed, planting green spaces, and preserving species biodiver-sity (Tomiltseva et al., 2017; Zahorodnia et al., 2010).

2.2. Research technique

In the work, a study of the ecological state of the Dnipro Reservoirs, their development, and identified revitalization technologies was carried out on the example of the Kremenchuk hydroelectric plant.

3. Results and Discussion

Kremenchuk Reservoir is located between the Kaniv and Kamian Reservoirs within the Poltava, Kirovohrad, and Cherkasy regions of Ukraine. The Kremenchuk HPP dam created the reservoir and was filled in 1959–1961. Let us note the only case in the history of Soviet Ukraine when the Plenum of the Central Committee of Ukraine voted against the construction of the Kremenchuk HPP and the flooding of the Dnipro valley on a large scale – almost 148 km long, up to 28 km wide in some places (the water height support mark was 81 m to the zero level of the Kronstadt rootstock). Two hundred twelve settlements were underwater. It is known that the flooded area could be halved by building dams. However, they chose an economically more profitable option in terms of invested resources and terms of execution. As a result, in addition to settlements, tens of thousands of valuable agricultural lands and forest areas were flooded (Fig. 1).

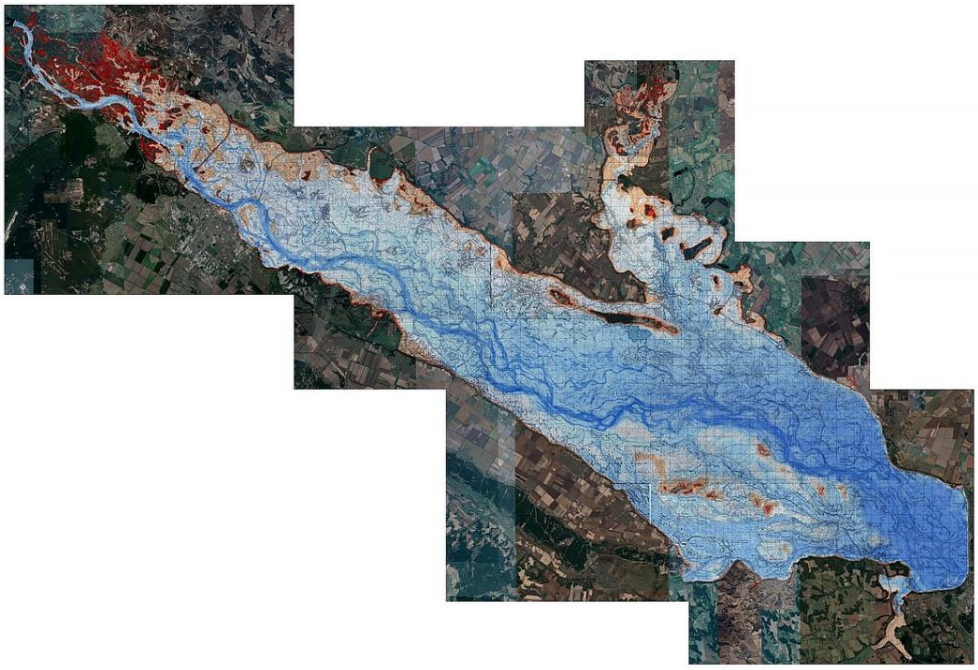

Fig. 1. The territory of the Kremenchuk Reservoir

The modern Kremenchuk Reservoir has a volume of 13.5 km³ (the second place in Ukraine), a coastline of 800 km, a length of 185 km, a maximum width of 30 km, and a maximum depth of 28 m. Water level fluctuation is 5.25 m. The shores are sandy, high (up to 30–40 m), steep, mainly under cliffs, separated by ravines, and characterized by erosion processes.

Environmental problems are increasing every year: banks are collapsing, reservoirs are thinning in coastal and island areas, excessive development of cyanobacteria (blue-green algae) leads to the degradation of the reservoir's self-cleaning biotic complex, and mass fish kills.

The discharge of phosphates and phosphonates provokes the development of bacteria into the Dnipro: through sewage (up to 70 %), car washes (20 %), and agricultural production (up to 5 %).

In current conditions, the deterioration of the ecological situation of reservoirs is influenced by the following factors: natural (global warming of the Earth, increase in average annual air temperature, decrease in average yearly precipitation; soil erosion in the catchment

area, destruction of banks, existence and expansion of shall-low water bodies; anthropogenic (sewage pollution, entry of polluting substances into water bodies in the pro-cess of surface water runoff from built-up areas and agricultural land; use of water for farming needs and industrial and technical purposes, the military aggression and ecocide caused by the aggressor state) .

Since 1901, the temperature of the warm period of the year and the daytime temperature have been increasing rapidly in Ukraine, the growth of which is more intensive than the growth of temperatures in the winter and night periods.

The rivers flowing into the reservoirs also carry solid rock particles and form a kind of underwater deltas and island lands, which, along with the erosion of the shores, expands the shallow water and silts up the reservoir up to 2 cm annually.

The above factors contributed to the expansion of shallow waters with a shallow depth (up to 2 m). The thickets of higher aquatic and terrestrial vegetation occupy 5 to 32 % of surface water. These areas are characterized by slow currents, reduced turbulent water mixing, and greater warming. The scope of shallow waters exceeded 40.000 hectares.

To monitor the "blooming" of water, the NDVI Index (Normalized Difference Vegetation Index) is a quantita-tive indicator of active (capable of photosynthesis) biomass (vegetation index). NDVI is the most widely used index. Thanks to satellite images, it is possible to observe trends in water surface conditions to monitor the spread of algae that cause water "blooms". For example, the NDVI index allows you to monitor algae develop-ment in the Kremenchuk Reservoir (Fig. 2).

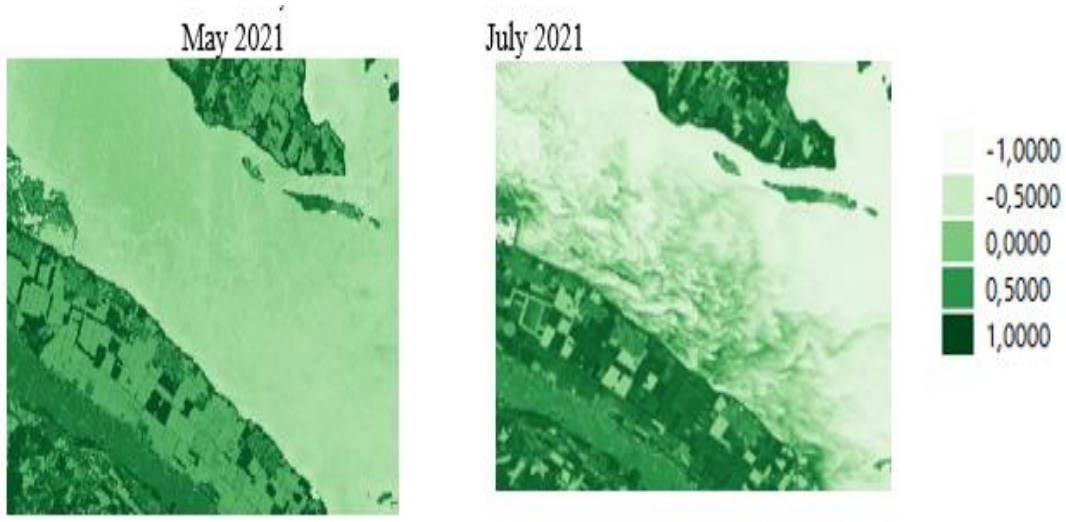

Fig. 2. Vegetation index NDVI reservoir (range from -1.0 to 1.0).
Sentinel 2 satellite image, channels 11-8-4. EO Browser resource, USGS Earth Explorer)

The shores of reservoirs are under the constant influence of water and waves, which contributes to the develop-ment of landslides and abrasions of soil rocks. Abrasion is the destruction of shores (oceans, seas, lakes, or large reservoirs) and the removal of stones in the coastal zone of reservoirs by waves and surf, abrasion of the shores of artificial reservoirs is called shore processing.

Various hydro-technical methods of shore fortification are used to combat landslides and shore abrasions: artificial sandy beaches and washes, stone capes, spurs, banquettes, and buns, as well as their various combi-nations, for example, almost a third, 43.9 km, of the shores of the Kremenchuk Reservoir needs urgent protection, because every year the water takes away from 2 to 7 m of the coast. To strengthen the areas, at least a billion hryvnias are needed (Sharyi et al., 2022).

Satellite images of the Kremenchuk Reservoir show the gradual overgrowth of the banks with reeds and reeds, as well as their shallowing (Fig. 3). Therefore, the degraded ecosystems of the Dnipro Reservoirs must be re-constructed without waiting for restoration due to chaotic natural entropy.

An analysis of the depths of a part of the Kremenchuk Reservoir indicates some existing areas of shallow water that can be revitalized through drainage, land reclamation, construction of dry land at the expense of leaching and backfilling, and returned to land for nature conservation purposes, recreation, forest fund, residential and public buildings, transport, energy (Fig. 4).

Fig. 3. The coastline of the Kremenchuk Reservoir near the village of Veremiivka, space images of 2008 and 2019

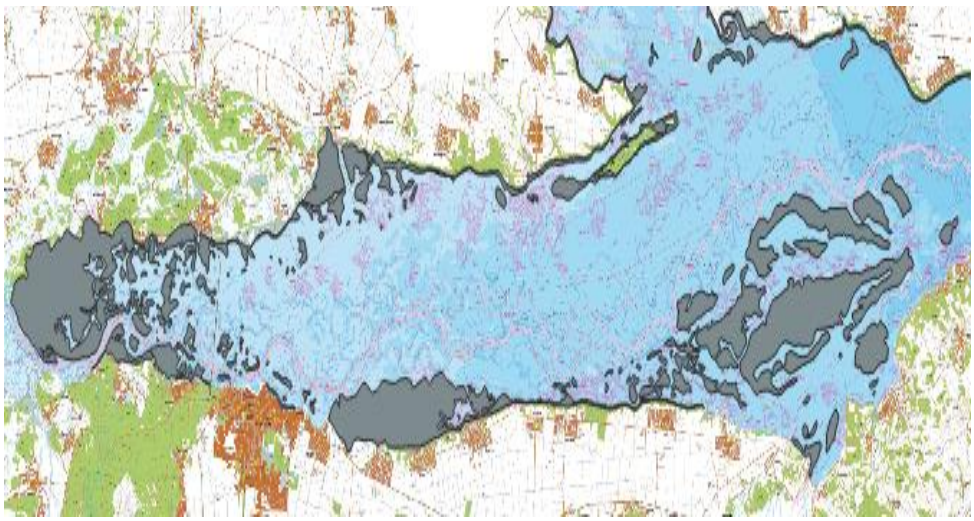

Fig. 4. Shallow waters of the Kremenchug Reservoir

The proposed to build bulk and alluvial complex "Veremiivska sich" (on the site of the flooded villages of Veremiivka and Tymchenko) of the peninsula and the entire archipelago of alluvial islands of various purposes for wind power and solar power plants, windbreak forest plantations, ports, transport, and sports facilities, fishing facilities, residential complexes, and sports recreation centres.

The Verkhovna Rada must adopt the Law of Ukraine "Program for the Development of the Dnipro Basin until 2050" (from now on the Program), which will provide for the stages of carrying out a complex of works and specific measures, both on the Dnipro hydroelectric nodes and tributaries, reservoirs, ponds, and adjacent territories; implement the actions of the Program in 3 stages: the first by 2030, the second by 2040, and the third by 2050:

– develop and adopt projects, having held a public discussion and expertise on the reconstruction of the Dnipro Reservoirs (until 2025);

– to provide for the financing of the Program with the funds of state and local budgets and investors, both domestic and international;

– adopt amendments and additions to the Tax Code and the Water Code for the targeted use of payments for the benefit of natural resources (land, water, hydrocarbons) exclusively for reclamation, land restoration, afforestation, land conservation, and the revitalization of reservoirs, rivers, wetlands, streams, disturbed industrial lands, and polluted areas;

– shore fortification of reservoirs, but not along the existing shoreline, but the edge of shoals (up to 2 m deep) with subsequent drying and flushing and revitalization (Kyivske, Kanivske, Kremenchutske, Dniprovske and Dniprodzerzhynske reservoirs);

– to provide for lowering every 5–10 years 1 m of the Kremenchutske Reservoir every year for reclamation and reconstruction;

– to implement the legislation of Ukraine regarding bans on the use of chemicals (phosphates) in everyday life and agriculture.

From the second stage of the implementation of the Program, the transition in Ukraine to the reconstruction of urban wastewater treatment systems, not only sewage but also rainwater in cities and villages located on the banks of rivers and streams of the Dnipro basin (until 2030-40 years), the Program provides for the construction of fish bypass channels and fish lifts.

The measures will partially make it possible to form a European-type ecological frame of the Dnipro basin.

4. Conclusions

Scientifically based revitalization of the Dnipro reservoirs through shore fortification, draining of shallow wa-ter, and deepening of the bottom will contribute to the elimination of stagnant areas, activation of water movement, and lowering of its temperature in the summer period by 5–6 ºC, will ensure the formation of con-stant currents and circulation of water in the reservoir. Furthermore, deepening the bottom will facilitate the alternation of cooled and heated parts for water circulation, increase the number of wintering pits for fish, and stop the excessive development of cyanobacteria in the summer.

It is necessary to change the paradigm and reform the legislative and institutional framework, supplementing the Land and Water Codes of Ukraine with legal provisions that regulate the conditions for the termination of the existence of a part of a water body and the reclassification of water fund lands into those designated for transport, residential and public development, recreation, forestry, energy, industry, agriculture, and nature conservation purposes.

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