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Technical and Environmental Problems Creation and Operation of a Rural Drinking Water Supply System in the Northern Steppe Areas of the Mykolaiv Region, Ukraine

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ABSTRACT

The article discusses the fundamental aspects of the water deficit problem in rural areas of the South Prydniprovska Upland, which is prevalent in the Mykolaiv, Cherkasy, Kirovohrad, and Dnipro regions. The study focuses on the rapid hydrochemical instability observed in locally accumulated runoff reservoirs, significantly deteriorating their water quality for consumer use. The inherently high salinity, exacerbated during peak water shortage periods, diminishes the significance of local hydrosystems as viable water sources. The swift advancement of autonomous filtration water treatment systems and artificial filtration in drinking water production necessitates a reevaluation of traditional principles in rural water supply. Concurrently, this development brings to light several critical technical issues with economic implications. Cost-effective decentralized water treatment for drinking purposes mandates the use of natural water with a salinity of up to 1.5–1.8 thousand mg/dm^3. Treating water with a salinity of 3–4 thousand mg/dm^3 would be economically unfeasible due to the need for accelerated replacement of filter elements, excessive electricity consumption, and extended working hours. Therefore, the challenge of accessing water reserves with minimal deviation in hydrochemical composition from drinking standards persists, as current reservoirs and water storage facilities do not meet this requirement. To rationally exploit available water reserves, the proposed principle of cascade-separate water use for small reservoirs is introduced. This approach is based on creating a tandem of existing channel ponds and small water storage reservoirs linked by regulated water flow. The satellite water storage ponds, filled from the surface with relatively clean, flotation-deposited water from the main pond, will contain a 3-4 month supply of conditionally high-quality water, ensuring efficient operation of drinking water treatment plants at a volume of up to 20 m^3/day. These relatively small (up to 0.5 million m^3) reservoirs are easy to maintain, clean, and periodically disinfect, meeting the minimum water quality requirements for preparation for drinking and the domestic needs of the population.

Keywords: rural water supply, drinking needs, reservoir, steppe area, Mykolaiv region.

INTRODUCTION

The Mykolaiv region, spanning 24.6 thousand km^2, stands as the most water-deficient region in Ukraine (the National Report, 2019). This deficiency significantly impedes the development of its natural and economic potential. The severity of the problem stems from the absence of underground deposits of high-quality drinking water and a simultaneous scarcity of surface water reserves suitable for fulfilling the drinking and domestic requirements of the population (Regional Report, 2019). The total average long-term river runoff in the region, considering runoff from adjacent forest-steppe areas, amounts to merely 3.4 km^3, a stark contrast to the overall Ukrainian runoff of 209.8 km^3. Within this, the local runoff is a mere 0.57 km^3, contributing to the larger local runoff of Ukraine, which stands at 52.4 km^3 (Analysis, 2021). This disparity underscores the critical nature of the water scarcity issue in the Mykolaiv region.

The freshwater reserves in the region primarily encompass precipitation, water inflows from the Southern Bug and Syniukha rivers, and groundwater. Notably, the volumes of groundwater are the smallest in Ukraine and exhibit significant variations in quality and operational potential. This diversity is further compounded by a mosaic spatial distribution (The state, 2021). Consequently, the Mykolaiv region grapples with a general shortage of fresh and conditionally fresh water suitable for subsequent treatment to meet domestic needs. This water scarcity issue is particularly acute in the north-eastern part of the region (National report, 2021). This specific area belongs to the fractured water zone of the Crystal Shield (Liuta, 2023). The ongoing water shortage remains a critical concern in this region.

Despite certain improvements in the drinking water supply situation by the end of 2023, thanks to the implementation of artificial water treatment plants, a substantial portion of the rural population in the former Arbuzynka, Bratske, Yelanets, Kazankivka, and Berezne-huvata districts still relies on imported drinking water (Program, 2018). Yelanets, with a population of 5,000, continues to lack centralized water supply due to the absence of local water sources. The community meets its domestic water supply needs through the utilization of low-quality and limited local groundwater, along with traditional rainwater harvesting practices (Environmental passport, 2022). The absence of prospects for improving the situation through the exploitation of deep groundwater is notable due to its high salinity, ranging from 3.6 to 11 thousand mg/dm^3 (Medical-hydro-geochemical factors, 2015). Additionally, expectations for the successful exploitation of local surface reserves are questionable, given the average annual rate of local runoff per capita is merely 0.012 thousand m^3/year. This is significantly lower than the regional average of 0.044 thousand m^3/year, representing a 2.38-fold decrease compared to the national average in Ukraine (Obukhov, 2019). The challenges in ensuring adequate water supply persist in this region.

The prolonged and locally critical water deficit in specific areas has left no alternative to external water supply, whether through mains or imported sources. For numerous settlements in the northern sub-territories of Mykolaiv region, external water supply has been, and continues to be, the sole economically viable means of securing water access (Resolution, 2000). Nevertheless, recent advancements in water treatment and purification technologies, encompassing biological methods (Malovanyy et al., 2021), adsorption techniques (Malovanyy et al., 2020), ion exchange processes (Kostenko et al., 2017) and reverse osmosis (Henthorne and Boysen, 2015), present promising opportunities for the production of ample volumes of drinking water. Consideration is also given to the purification and accumulation of water reserves for domestic needs. In the southern regions, there has been partial implementation of autonomous drinking water supply systems based on local water reserves in most territorial communities in recent years (Rural drinking water, 2016). The impediment to the widespread implementation of these local water treatment technologies lies mainly in the absence of necessary, year-round water supplies. Addressing this challenge has become exceptionally urgent in promptly resolving the issue of drinking water supply in rural areas.

MATERIALS AND METHODS

This study relies on the author's original field, laboratory, and analytical research, encompassing an assessment of the current ecological status and water management of surface water bodies in the Mykolaiv region. The factual materials amalgamate the most recent data spanning 2020-2023 concerning the hydrochemical characteristics of water and the ecological status of the Mertvovid River and its tributaries (Nakonechna et al., 2021). This information enables the generalization and derivation of current estimates regarding their potential as viable sources for drinking and domestic water supply. A substantial portion of the source material comprises factual data obtained from literature sources, reports from state and municipal institutions, and other relevant organizations. Mapping materials were collected using the Gis Map Server geoportal, employing the cross-platform geographic information system QGIS ver. 3.32.3 and the SAGA GIS 7.8.2 application. This combination of fieldwork, data analysis, and geospatial mapping contributes to a comprehensive assessment of the ecological and water management dynamics in the studied region.

In the examination of water bodies, a systematic approach was applied, treating each water body as an integral and independent hydrosystem. This encompassed the organic components, including all surface and groundwater within the catchment area, the river valley, the watercourse itself, and any existing channel ponds-reservoirs within the system.

The focal point of the study was the water bodies, and the investigation followed the standard methodological complex prescribed by the Water Code of Ukraine (Ministry of Ecology, 2019). Additionally, the study adhered to the State Standard of Ukraine, incorporating guidelines and recommendations for conducting hydroecological and water management studies on freshwater bodies, integral hydrosystems, and their respective basins. This comprehensive approach ensures a thorough examination of the ecological and water management aspects of each water body within the studied area.

Direct investigations of surface water bodies involved seasonal route surveys and field assessments. Hydrochemical and microbiological analyses of collected water samples were conducted in a certified water laboratory, a unit within the Department of Chemical Ecology at the Admiral Makarov National University of Shipbuilding in Mykolaiv. Further analytical and modeling studies in 2023 were performed at the Water Laboratory of the Leibniz Institute in Berlin, Germany.

Thus, the aim of the project is to develop a drinking water supply system for settlements in the Mykolaiv region within the fractured water zone, with the goal of providing safe drinking water. This will be achieved through the implementation of the latest technologies in local autonomous water treatment.

RESULTS AND DISCUSSION

The findings from hydroecological studies on surface water bodies and the primary sources of water supply in the north-eastern districts of Mykolaiv region, conducted between 2020 and 2022, highlight the acute challenges in providing drinking water to local rural communities. These challenges stem from the hydrogeological characteristics of the Sinyukha-Ingul interfluve, limited reserves of fractured groundwater, and the insufficient hydrochemical quality of surface water. The latter are in direct hydraulic interconnection and are equally influenced by environmental conditions (Kamzist and Shevchenko, 2009), creating a ‘vicious circle’ situation marked by direct and reverse dependencies. The essence of this situation lies in the fact that the minimal river runoff from the slopes of the South Prydniprovska Upland, coupled with increasing hydroclimatic aridity, virtually eliminates the water management potential of the existing watercourses. Their utilization is only feasible with the artificial accumulation of runoff in channel ponds and reservoirs, which will serve as future water supply facilities (Gopchenko and Loboda, 2005).

At the same time, the operation of storage reservoirs in the valleys of steppe rivers reveals several problematic phenomena associated with the disruption of natural hydrological mechanisms that stabilize their water balance. The primary factor is the intense evaporation from the surface of artificial reservoirs, leading to direct water losses and hydrochemical changes. These evaporation-induced losses are irreversible and offset (partially or completely) the hydroecological potential of natural runoff. The river water in the primary channel serves to maintain flow and recharge groundwater reserves, ensuring the ecosystem functionality of watercourses (Acreman et al., 2014).

Thus, the higher the water demand from the population, the greater the need for accumulation and storage, necessitating large reservoirs (10 million m^3 or more) capable of withstanding water losses. However, larger reservoirs also result in increased water evaporation. In recent years, the average evaporation from the surface of freshwater reservoirs in the study area has been 800-850 mm/m^2 (Shereshevskyi and Synytska, 2000; Snizhko et al., 2021). This means that at least 8000 m^3 of water is lost from 1 hectare (100x100 m) of the surface of well-purged channel reservoirs. In other words, the volume of water lost from 1 hectare of the water surface due to evaporation is equivalent to the annual volume of drinking water consumption in villages with a population of 5-6 thousand inhabitants. Such significant losses require appropriate compensation by runoff, which is currently insufficient, creating a ‘vicious circle’ in the cause-and-effect cycle.

Consequently, any contemporary design of water storage reservoirs for supplying water to settlements necessitates addressing the challenge of stabilizing their hydrological and hydrochemical state. The most advanced solution to this issue involves directing water into underground reservoirs, which serve as the primary means of accumulating and preserving fresh water reserves in the Desert zone. An intermediate alternative includes artificial deep water storage reservoirs with the smallest possible water surface area. An illustrative example is the Kudryavtsivske reservoir, boasting a volume of 1.19 million m^3 and covering an area of 9.2 hectares. This reservoir was strategically created in a narrow canyon (up to 11 m deep) at the summit of the Mertvovid River (Fig. 1).

The studied characteristics of this reservoir (Fig. 1), created for regulating runoff from the upper reaches of a small river, indicate the success of the project and its suitability for water storage purposes. Narrow and deep flowing water bodies with a small surface area are optimal for storing reserves of clean, flowing, and oxygen-saturated water with minimal filtration (rocky shores and riverbeds) and evaporative losses. Moreover, such water bodies provide favorable conditions for fisheries, requiring only the control of ichthyofauna density or its support through artificial feeding.

A detailed examination of existing channel ponds in the left bank of the Buzk Lowland, in comparison with the Kudryavtsivske reservoir, demonstrates their limited suitability for drinking water storage tasks. This limitation arises from neglecting the specifics of draining watercourses originating in highland areas belonging to the southern slope of the Ukrainian Crystalline Shield. They are characterized by significant surface and underground sediment transport and a complex ion composition (Hrebin, 2010), ensuring geochemical normalization of the South Prydniprovska Upland. The volumes of such transport are currently demonstrated by the full-flowing and fast-flowing Ingul, which maintains the migratory geochemical balance in the source areas throughout the year (Yehorova and Mokliachuk, 2014). If these migratory-main means of geochemical unloading of the drainage areas are blocked by artificial dams (barriers), accumulation of drainage components will occur instead of their transport. The most problematic consequence of this is the phenomenon of progressing water mineralization in river reservoirs, a vivid example of which is presented in Figure 2.

Yes, against the backdrop of the stability of indicators for the perennially flowing Kudryavtsivske reservoir, seasonal hydrochemical variability in the largest (except for Oleksandrivske and Sofiivske) reservoirs in the Mykolaiv region – Yelanetske, Shcherbanivske, and Taborivske – is significantly pronounced. The main cause of this phenomenon is the intensive accumulation of ion discharge from rivers in the valleys of Hnilyi Yelants and Mertvovid, partly stimulated by their negative water balance during the limited period. Small but dynamic plain reservoirs – Yavkynske, Barmashivske, and Liublinske – are also influenced by accumulation-drainage phenomena but are considerably leveled by periodic replenishment from the Ingul and Ingulets rivers.

Consequently, the pronounced hydrochemical instability (both long-term and seasonally

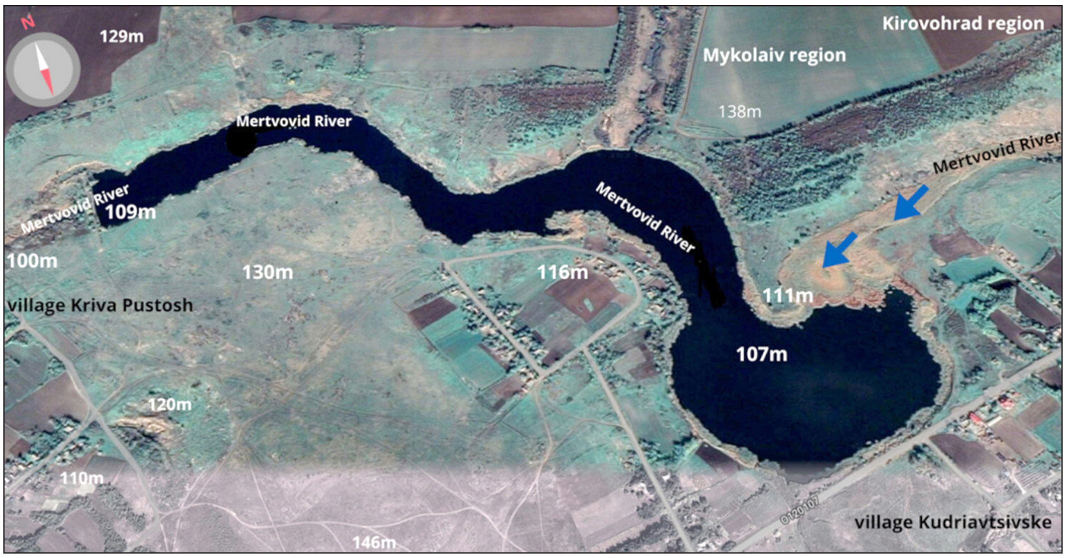

Fig. 1. Kudriavtsivske reservoir in the upper reaches of the Mertvovid

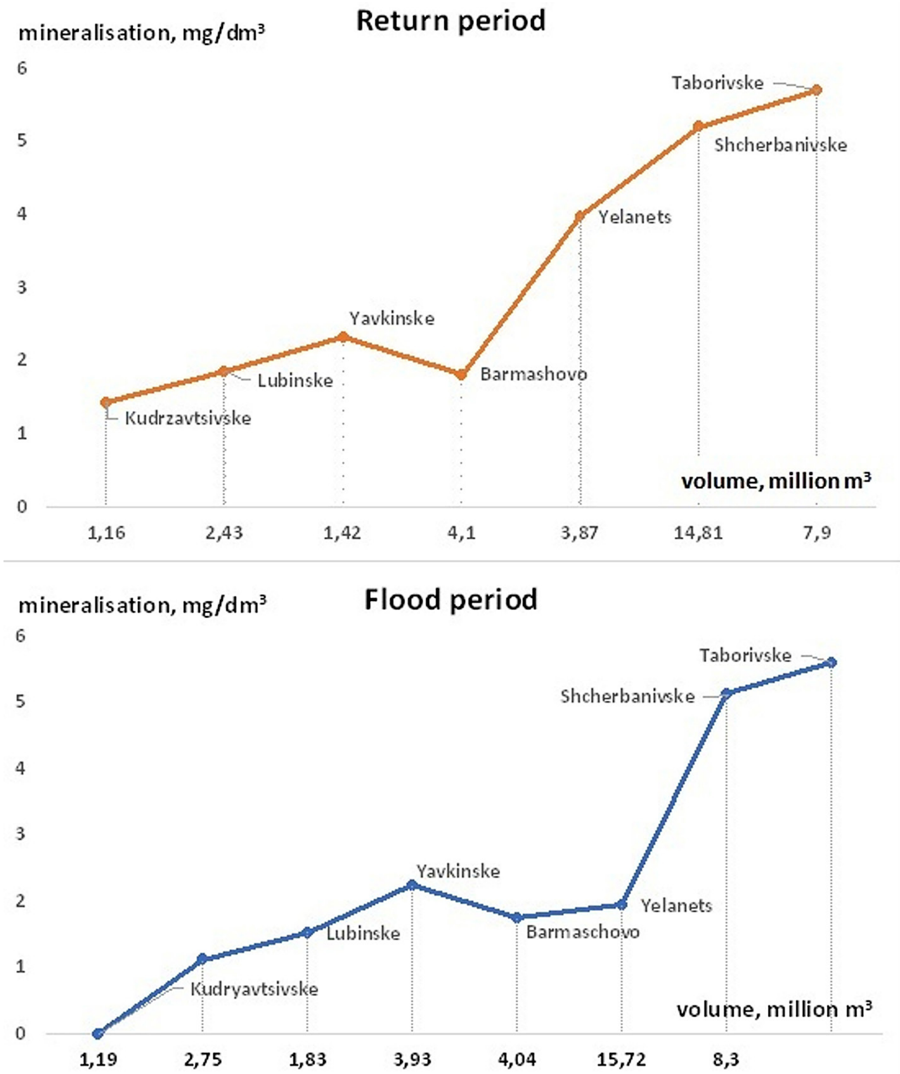

Fig. 2. Seasonal fluctuations in reservoir volume and water salinity occur during flood and return periods

short-term) of water in channel ponds operating within the studied territory is a significantly negative factor that noticeably degrades the consumer quality of accumulated river runoff. Elevated mineralization of water reserves in channel ponds of small rivers, especially during the peak period of their deficit, markedly complicates the water management potential of these watercourses. This became a key reason for the development of regional programs like "Drinking Water of Mykolaiv Region", designed for several stages of implementation. These programs covered various directions for the development of water supply facilities, but none of them envisaged the development of small rivers and their resources (Project, 2019; Mykolaiv Regional Council, 2019).

The emergence of modern autonomous filtration water treatment systems and artificial filtration methods for drinking water production has necessitated a review of the fundamental principles of previous water supply programs and has brought attention to several technical issues that are economically significant. The most efficient approach involves the use of natural water with a mineralization of 1.5–1.8 thousand mg/dm^3 for further purification to drinking conditions, whereas similar treatment of water with a mineralization of 3–4 thousand mg/dm^3 already requires three times more expenses per unit volume. This is due to the need for the accelerated replacement of filtering elements, payment for excessive electricity consumption, and working time. Thus, the problem of access to water reserves with minimal deviation in hydrochemical composition remains equally acute and is not addressed by existing reservoirs and water bodies.

Taking into account the experience of water management assessment from surface water bodies of the Mertvovid river basin and relying on general hydrological principles for the operation of channel ponds in the steppe zone (Pylypenko, 2007), a principle of cascade-separated water use was developed for the rational exploitation of existing water resources. The essence of this approach lies in creating a tandem of active channel ponds and small water storage reservoirs connected by regulated water flow. Water storage satellite reservoirs, replenished with surface water, relatively clean, and flotation sedimented, from the main pond, will be used only to supply drinking treatment facilities. Small (up to 0.5 million m^3) reservoirs are easy to maintain, clean, and periodically disinfect, meeting the minimum water quality requirements for drinking and household needs of the population. In case of flood threat, the «bloom» of water in the main ponds, or in case of hydrochemical destabilization, the water supply to the storage reservoir is blocked, and it is further used as a closed water reserve. Therefore, the minimum volume of the satellite reservoir should contain a 3–4 month supply for a particular settlement.

A similar, quite complex in real combination, set of conditions for designing the construction of a water storage pond was found only in the valley of the Komyshuvata River, a right tributary of the Mertvovid. The main water body chosen is the pond in the village of Serhiivske (Repiakhivka), located in the valley of the Komyshuvata River, 7 km upstream from the northern outskirts of Bratske town. The mentioned section of the river and its features are presented in Figure 3. The chosen location for creating a satellite pond is a canyon-like section of the currently empty natural riverbed, preserved between the left bank of the valley and the dam of the main pond.

The identified area proposed for the construction of a small storage reservoir (indicated in Figure 3 with a red square) represents a section of the natural riverbed of the Komyshuvata River. After the construction of the Repyakhivske channel pond in 1974 (up to a depth of 8 m), the old channel of the Komyshuvata River serves as a backup spillway, sometimes activated only in spring and during summer floods. The perennial flow of the pond is maintained by the spillway through a concrete pipe with a diameter of 1.7 m, embedded in the upper part of the dam (marked on the diagram with a large dashed line in light blue).

The small Komyshuvata River originates just above the village of Shyrokyy Rozdol, practically on the border of the Mykolaiv and Kirovohrad regions, only 9 km away from reaching the watershed between Mertvovid and Chorny Tashlyk.

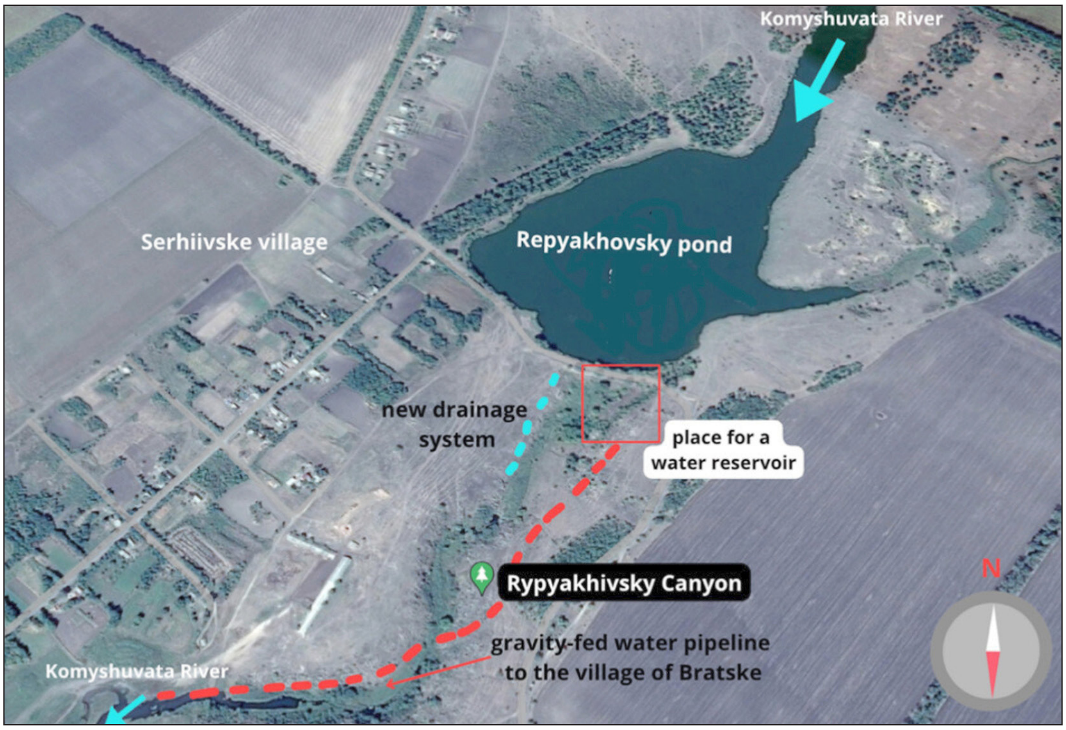

Fig. 3. The planned location of the water storage reservoir in the Komyshuvata River valley

The total length of the river is 27 km (32 km to the extreme source point), with a catchment area of 156 km², and the flow direction is southwest. The valley widens and deepens significantly from the top, passing through several rocky canyons in the middle stream. The largest of them is the canyon within the village of Serhiivka, below which there are three more small canyons near the village of Serhiivske (Repyakhivka). Below the canyons, the Komyshuvata River valley takes on a channel-like type, reaching a width of 1.3 km and a depth of 43 m. The average slope of the riverbed from the source to the mouth is quite significant – 3.6 m/km. The riverbed is winding, occasionally silted, and obstructed by dams (Yatsyk et al., 1991). One of these dams created the Repyakhivske pond, which, despite its relatively small water surface area (11 hectares), contains a significant water reserve (3.2 million m^3).

From the village of Obukhivka to the mouth, located within the village of Bratske (23 km along the riverbed), the Komyshuvata River flows perennially. Seasonal measurements (2020–2022) of the river's flow volume orient the annual average indicator (Qavg.) within the range of 0.028 m^3/s. Seasonal fluctuations in flow are quite significant – from 1.12 m^3/s in spring to 0.011 m^3/s in September-October. Along with changes in flow volume, there are changes in mineralization – from 680 mg/dm^3 in spring to 1900 mg/dm^3 in late summer-autumn. The examination of the current Repyakhivske pond and its downstream area, which is planned for the storage reservoir, allows for the formation of the project location of the dam in the ancient channel part of the natural talweg, without disrupting existing drainage paths (Fig. 4).

The calculated parameters of the main (existing) Repyakhivske pond are as follows: the dam height above the upper edge is 96 m above sea level, the water level is 93 m above sea level, the height difference from the top of the dam to the natural bottom of the channel is 11 m, from the water level to the channel's bottom is 8 m. The elevation of the bottom downstream (at 0.45 km) of the Repyakhivske canyon is 78 m, the elevation of the Komyshuvata River bed before the bridge at the entrance to Bratske is 75 m, and the water level of the river at its confluence with the Mertvovid is 72.2 m. The total distance from the proposed dam to the western outskirts of Bratske is 5.69 km, and along the channel to the mouth is 7.36 km. The calculated working volume of the storage reservoir is 250 thousand m³ of water, and the maximum volume (up to the upper cut of the proposed dam) is 270 thousand m³ of water. The profile projection of the reservoir heights is shown in Figure 5, which depicts the heights, the profile of the natural channel, the existing dam,

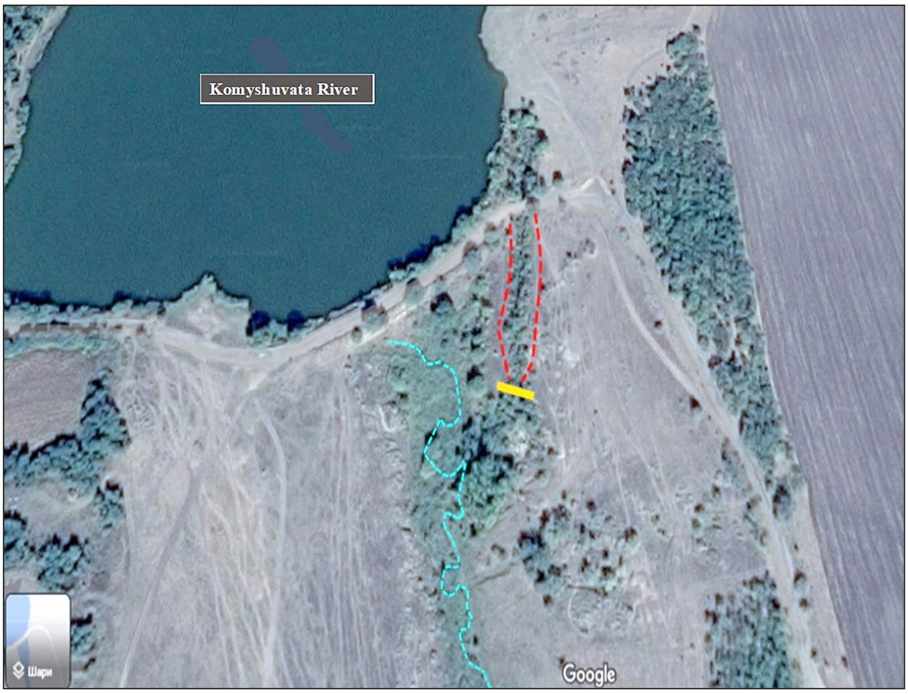

Fig. 4. Approximate location of the dam and the storage reservoir below the dam of the Repyakhivske pond in the channel of the Komyshuvata River

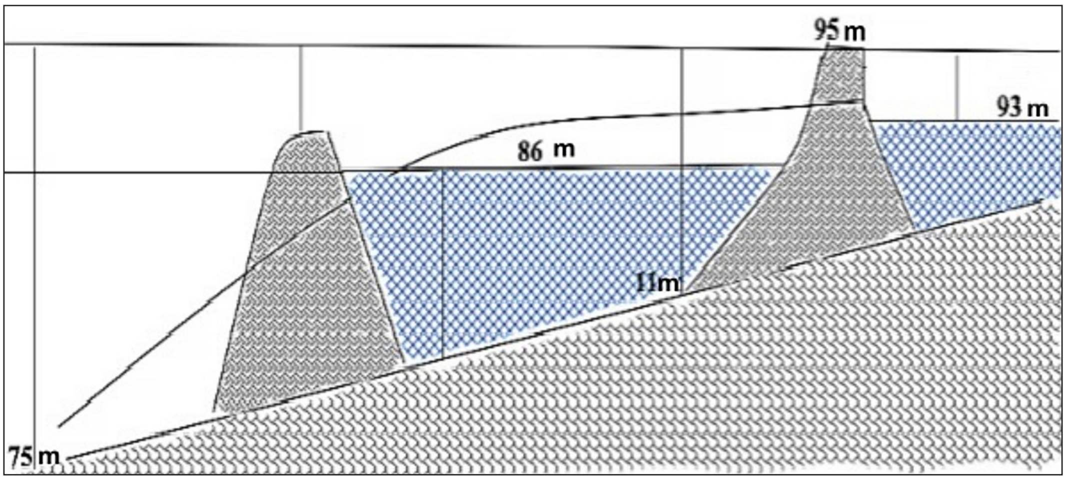

Fig. 5. Heights and profile of the channel and dam of the existing Repyakhivske pond along with the proposed dam of the storage reservoir, view from the left bank of the Komyshuvata River

and the proposed dam of the storage reservoir. The maximum depth of the lower reservoir in front of the dam is 7.1 m.

The projected area and location of the lower reservoir are outlined with a red dashed line on Figure 5 and cover an area of 2.79 hectares, of which 2.21 hectares is the water surface area when the reservoir is filled to the working level. A positive aspect of the location and the proposed structure of the separating water bodies is the possibility of using the first, deeper Repyakhivske pond for primary flotation holding of water with subsequent discharge of the upper, oxygen-saturated and partially purified waters to the lower storage reservoir. In addition, the emergency discharge in the center of the upper dam remains functional. The combined discharge capacity of both outlets is over 300 m³/min, which is three times higher than the largest recorded flow volumes of the Komyshuvata River.

A more detailed scheme of the construction of the lower reservoir (storage), emergency discharges, and the overall complex of the proposed structure is presented in Figure 6, which shows a top view and a projection of the banks of the Sergiivske canyon. Detailed scheme of the construction of the lower reservoir, emergency discharges, and the overall complex of the proposed structure, top view and projection of the banks of the Sergiivske canyon. Water intake from the reservoir of the

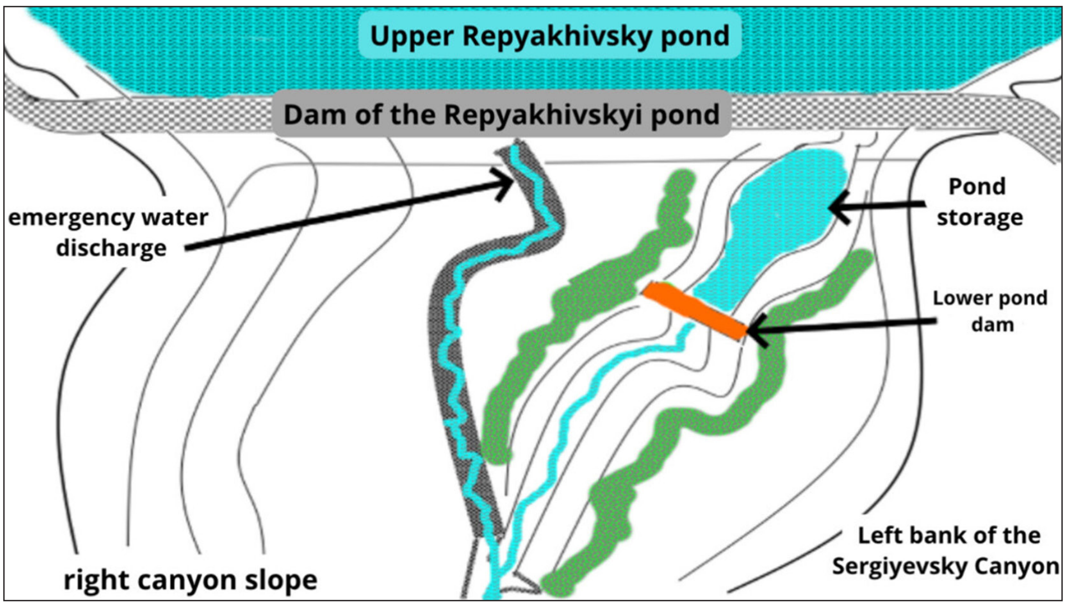

Fig. 6. The upper and lower ponds and their spillways within Serhiyivka Canyon

lower pond is planned from the left bank and will continue to run along the left side of the Komyshuvata valley, allowing gravity water supply to the outskirts of Bratske village with further supply to the point(s) of treatment and supply to consumers. According to preliminary calculations, considering the spatial structure of the main facilities requiring significant volumes of water (cheese factory, schools, enterprises), the water supply system of the village should have a separate structure. For this purpose, the most rational scheme is to distribute the primary water supply from the water storage reservoir to three equidistant parts of the settlement. This arrangement of three reverse osmosis units in different parts of the village is currently in operation, but it does not have its water supply and uses imported water. Another unit is in operation at school No. 2 and is fully used to meet the needs of the school. The three existing reverse osmosis plants produce 12 m^3 of drinking water daily, but the project envisages a daily capacity of 30 m^3 of treated water. Besides the spatial advantages of spreading water treatment facilities for the population, their location in different parts of the village allows them to cover the needs during the period of preventive maintenance or repair of one of the plants, if necessary.

CONCLUSIONS

This study addresses the critical issue of drinking water supply in rural areas of the northern part of the Mykolaiv region. The findings lead to the following conclusions. The study identifies the primary factors contributing to the drinking water deficit across the South Prydniprovska Upland. The artificially accumulated water reserves in river reservoirs face challenges in long-term storage due to significant evaporation and the influence of highly mineralized groundwater. Evidence indicates an escalation in salinity levels in the waters of major reservoirs in the region (Taborivske, Yelanets, Shcherbanivske), limiting their water management potential.

Seasonal instability and unsuitability for drinking and domestic use characterize artificially created surface water reserves sourced from local river runoff. Specialized multi-stage treatment is necessary. Presently, the rural population in the northern part of Mykolaivska relies on local water reserves for drinking water access. However, the shortage of these reserves remains a primary obstacle to obtaining a sufficient volume of water suitable for domestic use.

A proposed model for constructing a water supply system for the village of Bratske (5,000 inhabitants) accounts for existing water treatment technologies, local hydrological and hydrochemical specifics of artificial reservoirs, and separate water storage. This approach considers economically favorable conditions for local drinking and domestic water supply.

The calculated values obtained for water reserve formation, means of transportation to consumers, and the principles of organizing settlement water supply determine the reasonable, maximum possible economic effect of developing local water reserves to obtain sufficient volumes of high-quality water.

Future research prospects involve detailed exploration of the technological and logistical complex of local water supply for the northern districts of the Mykolaiv region, where water shortages significantly impede socio-economic development.

REFERENCES

1. Acreman M., Arthington A.H., Colloff M.J., Couch C., Crossman N.D., Dyer F., Overton I., Pollino C.A., Stewardson M.J., Young W. 2014. Environmental flows for natural, hybrid, and novel riverine ecosystems in a changing world. Frontiers in Ecology and the Environment, 12(8), 466-473. doi.org/10.1890/130134
2. Analysis of current factors of deterioration of the quality of drinking water supply in the context of Ukraine's national security. Analytical note 2021. Kyiv: National Institute for Strategic Studies. (in Ukrainian)
3. Environmental passport of Mykolaiv region for 2021. 2022. Mykolaiv. Retrieved from: https://ecolog.mk.gov.ua/store/files/2021%20%D1%80%D1%96%D0%BA.pdf. (in Ukrainian).
4. Gopchenko E.D., Loboda N.S. 2005. Water resources of the North-West Black Sea region (natural and conditions disturbed by economic activity). Kyiv: KNT. (in Russian)
5. Henthorne L., Boysen B. 2015. State-of-the-art of reverse osmosis desalination pretreatment. Desalination, 356, 129-139. doi.org/10.1016/j.desal.2014.10.039.
6. Hrebin, V.V. 2010. Modern water regime of rivers of Ukraine (landscape-hydrological analysis). Kyiv: Nika-Center. (in Ukrainian)

7. Kamzist Zh.S., Shevchenko O.L. 2009. Hydrogeology of Ukraine. Textbook. Kyiv: INKOS. (in Ukrainian)
8. Kostenko E., Melnyk L., Matko S., Malovanyy M. 2017. The use of sulphophtalein dyes immobilized on anionite Ab-17X8 to determine the contents of Pb(Ii), Cu(Ii), Hg(Ii) and Zn(Ii) in liquid medium. Chemistry & Chemical Technology, 11(1), 117-124. doi.org/10.23939/chcht11.01.117.
9. Liuta N.H. 2023. The current state and prospects of groundwater use in the aquifer of the fractured zone of crystalline rocks (hydrogeological region of the Ukrainian Shield). Bulletin of Taras Shevchenko National University of Kyiv. Series Geology. 2(101), 111–116. (in Ukrainian) doi.org/10.17721/1728-2713.101.16.
10. Malovanyy M., Moroz O., Popovich V., Kopiy M., Tymchuk I., Sereda A., Krusir G., Soloviy Ch. 2021. The perspective of using the open biological conveyor method for purifying landfill filtrates. Environmental Nanotechnology, Monitoring & Management, 16, 100611. doi.org/10.1016/j.enmm.2021.100611.
11. Malovanyy M., Palamarchuk O., Trach I., Petruk H., Sakalova H., Soloviy Kh., Vasylinych T., Tymchuk I., Vronska N. 2020. Adsorption extraction of chromium ions (III) with the help of bentonite clays. Journal of Ecological Engineering, 21(7), 178-185. doi.org/10.12911/22998993/125545
12. Medical-hydro-geochemical factors of the geological environment of Ukraine. 2015. (Ed.) Rudko G.I. Kyiv-Chernivtsi: Bukrek. (in Ukrainian).
13. Ministry of Ecology and Natural Resources of Ukraine. Order No. 5 of January 14, 2019. On approval of the methodology for assigning a surface water body to one of the classes of ecological and chemical status of a surface water body, as well as assigning an artificial or significantly modified surface water body to one of the classes of ecological potential of an artificial or significantly modified surface water body. (in Ukrainian) Retrieved from: https://zakon.rada.gov.ua/laws/show/z0127-19#Text.
14. Mykolaiv Regional Council. 2019. Decision No. 4 of 19.09.21 on approval of the regional program "Drinking Water of Mykolaiv Region" for 2021–2025. (in Ukrainian) Retrieved from: https://www.mk-oblrada.gov.ua/UserFiles/decree/1633434255615c3a8f16115.pdf.
15. Nakonechna Yu.O., Chugai A.V., Remeshevska I.V. 2021. Mineralization of waters of the Mertvovid River as an indicator of suitability for intended use. Bulletin of the Uman National University of Horticulture, 1, 121-128. (in Ukrainian) doi.org/10.31395/2310-0478-2021-1-121-128.
16. National report on the quality of drinking water and the state of drinking water supply in Ukraine in 2019. 2020. Kyiv. (in Ukrainian)
17. National report on the quality of drinking water and the state of drinking water supply in Ukraine for 2020. 2021. Kyiv. (in Ukrainian)
18. Obukhov Ye.V. 2019. Indicators of water supply to the population of Ukraine at the beginning of 2019. Hydropower of Ukraine, 1-2, 31-36. (in Ukrainian)
19. Program for the Development of the Water Sector in Mykolaiv Oblast for 2019–2021. 2018. Approved by the Regional Council on December 21. No. 35. Mykolaiv. (in Ukrainian)
20. Project "Mykolaiv Region Development Strategy for 2021–2027". 2019. Mykolaiv. Mykolaiv Regional State Administration. (in Ukrainian)
21. Pylypenko Yu.V. 2007. Ecology of small reservoirs of the Steppe of Ukraine. Monograph. Kherson. Oldi-plius. (in Ukrainian)
22. Regional report on the state of the environment in Mykolaiv region in 2019. 2020. Mykolaiv. (in Ukrainian).
23. Resolution of the Cabinet of Ministers of Ukraine of November 23, 2000. No. 1735. On the comprehensive program of priority provision of rural settlements using imported water with centralized water supply in 2001–2005 and forecast to 2010. (in Ukrainian). Retrieved from: https://zakon.rada.gov.ua/laws/show/1735-2000-%D0%BF#Text.
24. Rural drinking water supply: from idea to implementation. How to create a centralized water supply system in a decentralized way [methodological manual]. 2016. Kyiv (in Ukrainian). Retrieved from: https://hromady.org/wp-content/uploads/2020/11/Despro_voda_print.pdf.
25. The state of groundwater in Ukraine. Yearbook. 2021. Kyiv: State Service of Geology and Mineral Resources of Ukraine, State Research and Production Enterprise "State Information Geological Fund of Ukraine". (in Ukrainian)
26. Shereshevsky A.I., Sinitskaya L.K. 2000. Evaluation of changes in evaporation from the water surface on the territory of Ukraine. Scientific works of UkrNDGMI, 248, 67-76. (in Ukrainian)
27. Snizhko S., Shevchenko O., Didovets Yu. 2021. Analysis of the impact of climate change on water resources in Ukraine (full report on the project results). Center for Environmental Initiatives “Ecoaction” (in Ukrainian). Retrieved from: https://ecoaction.org.ua/wp-content/uploads/2021/06/analiz-vplyvu-vodni-resursy-full.pdf
28. Yatsyk A.V., Byshovets L.V., Bohatov Ye.O. 1991. Small Rivers of Ukraine. Ed. by A.V. Yatsyk. Kyiv, Urozhai. (in Ukrainian)
29. Yehorova T.M., Mokliachuk L.I. 2014. Ecological and geochemical processes of molybdenum migration in agricultural landscapes of Ukraine (in Ukrainian). Agroecological Journal, 2, 17-25.