



[https://doi.org/  
10.15407/ugz2024.04.012](https://doi.org/10.15407/ugz2024.04.012)

UDC 556:502.12:626.8(477)(045)

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## Modern Anthropogenic Hydrosphere of Ukraine

The purpose of the research is to analyze the formation and current state of the anthropogenic hydrosphere of Ukraine with a view to its rational use. Utilized methods include field research, literary-cartographic, collecting and processing statistical information, theoretical generalization and systematization of facts, and GIS technologies. It is shown that active anthropogenization from the Upper Palaeolithic until now has led to the replacement of the natural hydrosphere of Ukraine by the anthropogenic one. Various types of soil melioration and the formation of irrigation, drainage, and irrigation-drainage systems facilitated this process. The construction of numerous reservoirs (1,054) and ponds (49,440), derived reservoirs, and surface and underground water objects added to the problem. The processes of anthropogenization of the natural hydrosphere of Ukraine are examined in more detail, drawing on the example of small (the Silnytsia), medium-sized (the Trubizh), and large (the Pivdennyi Buh and the Dnipro) rivers. It was noted that overloading reservoirs, ponds, and melioration systems of most small and medium-sized rivers have completely lost their natural properties and features. In part, this also applies to large rivers, particularly the Dnipro. Only a 30–40 km long section of the river and its floodplains retained their natural state. Reservoirs account for the rest of its sections. They form an aquamarsh area with Europe's largest complex of hydraulic engineering structures. Despite this, landscape scientists and hydrologists continue to study rivers, reservoirs, ponds and, in part, canals individually. The novelty of the research consists of revealing the spatial-temporal features of the transformation of the natural hydrosphere of Ukraine into an anthropogenic one, as well as a thorough analysis of its current state.

*Keywords:* hydrosphere, anthropogenization, anthropogenic hydrosphere, water objects, state, rational use.

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## Сучасна антропогенна гідросфера України

Мета дослідження — здійснити аналіз формування та сучасного стану антропогенної гідросфери України для її подальшого раціонального використання. Методи дослідження: польових досліджень, літературно-картографічний, збору та обробки статистичної інформації, теоретичного узагальнення та систематизації фактів, ГІС-технологій. Показано, що активна антропогенізація з верхнього палеоліту до сьогодення призвела до заміни натуральної гідросфери України антропогенною. Цьому сприяли різні види меліорації та формування зрошувальних, осушувальних, зрошувально-осушувальних систем; будівництво в Україні численних водосховищ (1054) та ставків (49 440), похідних водойм, підземних водних об'єктів, наземних і підземних водотоків. Новизна дослідження полягає у виявленні просторово-часових особливостей трансформації натуральної гідросфери України в антропогенну та сучасного стану останньої.

*Ключові слова:* гідросфера, антропогенізація, антропогенна гідросфера, водні об'єкти, стан, раціональне використання.

### Relevance of the research

From the Upper Palaeolithic (40–30 thousand years ago) to the present day, the economic development of Ukraine's hydrosphere—springs, streams, rivers, marshes, lakes, sea coasts, and underground waters—

has been continuous, diverse, active and not always scientifically based. As a result, many of these water objects, mainly the headwaters of small rivers, have disappeared. The only thing left of some rivers is

their direction. Subsoil waters are often polluted and their upper (1–3) horizons are gradually disappearing. In Ukraine's large cities and industrial regions, an underground network of pipeline rivers and even pools (made of metal, concrete, and plastic) is being formed.

In general, natural components of Ukraine's hydrosphere are not only overly regulated by reservoirs, but also rebuilt—deepened, straightened, turned into swamps or destroyed. Since the second half of the

20<sup>th</sup> century, the hydrosphere of Ukraine has been significantly supplemented by an extensive network of canals and large (in terms of area and volume of water) reservoirs on medium-size and large rivers. All the above has led to the formation of a new, anthropogenic hydrosphere of Ukraine. Investigations into this new phenomenon are not only relevant but urgent as well. Studying the anthropogenic hydrosphere of Ukraine with a view to its further rational use calls for substantial scientific endeavors.

### Problem statement and major works

The issue of anthropogenic impact on water objects has long been the focus of attention of Ukrainian scientists [1–8]. An in-depth analysis of their research findings requires a separate monograph publication. Within the framework of this study, we mean to emphasize the following:

a) Rivers (not water objects in general, let alone Ukraine's anthropogenic hydrosphere as a whole) have long been the subject of analysis by Ukrainian scientists, including geographers, hydrologists, landscape scientists, etc. [2, 3, 6, 10–12].

The beginning of the comprehensive study of Ukraine's modern anthropogenic hydrosphere was made in the doctoral thesis of V. I. Vyshnevskiy in the early 21<sup>st</sup> century [2]. Among other things, the above research is focused on the anthropogenic impact on the rivers of Ukraine. The author looked into the matter of climate changes and their impact on river flow, the impact of the economic complex on the flow regulation and hydrological regime, sediment discharge and channel processes, water temperature, and hydrological characteristics of rivers. Based on his research findings, V. I. Vyshnevskiy proposed to single out a new direction of scientific knowledge referred to as anthropogenic hydrology, the object of study of water objects changed due to economic activity. They also include objects similar to natural ones that arose during economic activity. In fact, it was an entry into the anthropogenic hydrosphere of Ukraine. However,

in his later studies V. I. Vyshnevskiy returned to the focus on rivers of Ukraine alone [3, 10]. Among similar investigations prevail those into the anthropogenic impact on the rivers of Ukraine [1, 8, 12–14]. A comprehensive study of natural, anthropogenically altered, and technogenic limnosystems of the zone of mixed coniferous and broad-leaved forests of Ukraine—water objects, which include lakes, reservoirs, and ponds, was first carried out by L. V. Ilyin [15], can be a model for similar searches in other natural zones and mountain systems of Ukraine. However, comprehensive regional investigations into the formation and functioning of the modern anthropogenic hydrosphere of Ukraine are scarce. This article is an attempt to carry out such a study.

b) The vast majority of studies of anthropogenic impact on rivers look into a limited group of issues, such as the impact of flow regulation on rivers, irreversible water consumption, as well as activities on the catchment—plowing, deforestation, drainage, etc. [2, 3, 12, 16];

c) Scientists single out the climatic (warming) and anthropogenic factors as the two major factors affecting the current state of rivers. However, nowadays and before, the climatic factor draws the major attention of scientists [7, 11, 12, 17].

**The research's purpose** is to analyze the formation and current state of Ukraine's anthropogenic hydrosphere for its further rational use.

### Research methods

In the course of studying the modern anthropogenic hydrosphere of Ukraine, comparative, systemic, and ecological research approaches were used. Relevant scientific principles included objectivity, causality, evolution, and adaptability. General and specific scientific methods were applied. In particular, the field research in river basins involved using generally recognized landscape science methods: profiling, mapping, landscape analysis and synthesis, historical-landscape analysis, the method of analogy and

results, surveys of local residents, analysis of various literary and cartographic materials of regional archives and local history museums. Methods of processing statistical data of water resources basin management, in particular statistics of the Pivdennyi Buh and the Dniester water management situations, methods of deciphering Sentinel and Landsat space images, as well as materials from the Google Earth service, were also employed. In general, the methods of GIS technologies were used as cross-cutting ones.

### Statement of basic materials

*Spatial-temporal aspect.* The current state, major features and properties of the hydrosphere (anthropogenic water network and aquatic anthropogenic landscapes) of Ukraine are determined by the spatial-temporal features of the economic development. More than 40,000 years ago (Upper Palaeolithic), the first settlements emerged on the banks of rivers of the present-day Ukraine. The main centres of settlement in the Palaeolithic were the Middle Dniester and the Middle Dnipro. The topography of the settlements is determined by the two key factors: hydrological (water level fluctuations in rivers, the proximity of drinking water sources) and economic (areas most suitable for hunting, fishing and gathering were settled) ones. In the Dnipro region and the Dniester region, dwelling sites were found close to modern IV and V terraces and capes; in even lands of Ukraine, especially the steppes, they were found in river valleys and in streams where flint comes to the surface. In Polissia, certain settlements were found on islands and dunes. Almost 7 thousand years ago, in the floodplains and the first terraces of the valleys of the Pivdennyi Buh and the Dniester, the first Trypil Buh–Dniester agricultural culture in Eastern Europe developed (6–4 thousand years ago). Small (0.7–1.2 ha) temporary settlements and partial ploughing of floodplains affected the state of river-beds. However, due to local distribution, they did not cause fundamental changes.

The first significant changes in riverbeds' structure were due to their use as waterways for trade. As early as in the 2<sup>nd</sup>—the early 1st millennium BC, the Pivdennyi Buh, the Dnipro, and their tributaries were of considerable importance in trade relations of the population around the Dnipro–Buh estuary with the Aegean world. The rivers and overland routes that were used for doing trade in those times were called “God’s” roads. From Kryvyi Rih region, through the Ingulets River, the ancient centres of the Dnipro–Buh estuary received iron ores, special types of stone for making molds in iron smelting, etc. Swamp ores were mined in areas of forest-steppe and mixed coniferous and broad-leaved forests, in river-beds, swamps and lakes. Boats found in the peatlands of the Supii River, near the village of Pishchane of Cherkasy Oblast, and at the bottom of the Pivdennyi Buh River in Vinnytsia Oblast were means of transportation in those times. Both vessels were single-masted boats about 2.5 m long and could carry cargo up to 300–400 kg. In ancient times, the first stone fences and gates were built on the Pivdennyi Buh River and its tributaries [18]. In some places, they levelled rivers, simultaneously increasing their depth. In others they formed

the first anthropogenic reservoirs for economic needs.

The construction of dams, ponds, reservoirs, and canals caused radical changes in the landscape structure of riverbeds and their floodplains. Small rivers and their floodplains “took the first blow upon themselves.” At the beginning of the 1<sup>st</sup> millennium AD, small dams could already be found on small rivers of present-day Ukraine. Flooded canals were built in the floodplains of rivers around fortified settlements. The ability to block the river, dig canals, and, when needed, to “trickle down water” on the enemy—was well known in Kyiv Rus. With such an ability to use water, constructing “water” mills was not difficult for “strong-minded” artisans. The first mills likely appeared in Kyiv Rus in the 10<sup>th</sup>–11<sup>th</sup> centuries in the Galician and Volhynia principalities, which had close ties with Western Europe.

The invasion of the Tatar-Mongols (13<sup>th</sup>–15<sup>th</sup> centuries) weakened the process of economic development of the rivers. The development was not stopped completely, though. Mills on church lands in the dioceses of Kyiv, Volhynia, and Galicia are mentioned in the Khan labels of the 13<sup>th</sup> century, which were issued to the Russian clergy (the Mengu-Timur label is meant). Moreover, from the end of the 13<sup>th</sup> to the beginning of the 14<sup>th</sup> century, they began to build primitive mills for paper factories and metallurgical production on rivers or specially dug canals.

The revival of the economic development of water resources is observed at the end of the 15<sup>th</sup> and 16<sup>th</sup> centuries. This was due to the intensive settlement of Ukraine’s territory and the increased demand for Ukrainian fish in the European (particularly Polish and German) market. In the 16<sup>th</sup>–17<sup>th</sup> centuries, many ponds were built on small rivers of the forest-steppe of Ukraine. There was a constant struggle between feudal lords for the river lands where fishing could be organized. Four ponds of Velykyi Lityn, on the Zgar River, in 1631 gave a profit of 3,330 zlotys. The income from the ponds of the city of Starokostyantyniv on the Sluch River amounted to 4,000 zlotys and in Ternopil—16–12 thousand zlotys annually [19]. In the 1570s, Bar Starostat owned 25 ponds and 15 mills. Ponds were becoming an integral part of the forest-steppe landscapes of Right Bank Ukraine, they were displayed on political-administrative, military and other maps. The area of the pond created in the 17<sup>th</sup> century on the Zolota Lypa River, near the village of Berezhany, measured 430 desiatins (468 hectares); the length of the dam was more than a kilometer [20]. On the maps of H. Boplan (17<sup>th</sup> century), chains of ponds are shown

in the upper reaches of the Murafa and the Murashka rivers (the Dniester basin), on the tributaries of the Pivdennyi Buh—the Zgar, the Riv, the Sob, the Silnytsia, the Buzhok and on the tributaries of the Dnipro—the Sluch, the Teteriv, the Ros [21]. More than 240 ponds and 130 mills operated in the territory of Podillia at the end of the 17<sup>th</sup>—the beginning of the 18<sup>th</sup> centuries. The so-called “wild ponds,” which were created with the help of small dams, were widespread on small rivers and streams. At the end of the 18<sup>th</sup> century, most of the forest-steppe rivers, some rivers of the southern part of the mixed coniferous and broad-leaved forests, and the northern steppe were regulated, and ponds occupied their floodplains.

Active economic development of rivers was observed in the 19<sup>th</sup> and early 20<sup>th</sup> centuries. The development of shipping required relevant conditioning work on streambeds. In the area of the city of Yampil on the Dniester, as well as between the villages of Hnivan and Mizyakiv on the Pivdennyi Buh, rapids were destroyed, river-beds were deepened, floating mills (there were 12 of them near the village of Melnytsia-Podilska on the Dniester), canals, and wharves were built. At the beginning of the 19<sup>th</sup> century, along the Zbruch River, there were “23 water-powered mills, with a high dam near each of them, which made the river 20 fathoms wide and increased the depth to 10 feet” [20]. More than 110 large ponds are shown on the map of Vinnytsia District (1912), of which 42 were created on the site of former “wild” ponds; the process of layering their bottom sediments began. As early as the beginning of the 20<sup>th</sup> century, small rivers of the forest-steppe of Ukraine were regulated. During the First World War, the construction of ponds and mills stopped. “Now, there are other things to worry about apart from ponds. Dams and sluices are broken for military purposes, and ponds shine with empty bottoms” [22].

The reconstruction of pond farming and river mills on small rivers of Ukraine began at the end of the 1920s—in the 1930s. In 1932, there were 334 water mills in Kamianets-Podilskyi District alone and 751 in Tarnopil Voivodeship [20]. More than 2,500 ponds functioned in the Pivdennyi Buh basin, ⅔ located within the forest-steppe. Such tributaries as the Zgar, the Desenka, the Sob, the Riv, and the Silnytsia were chains of ponds (one pond per 3–4 km). However, most of the ponds of the forest-steppe Pobuzhzhia were silted up and overgrown. Such ponds reached 43% on the Riv River, the Vovk—57%, and the Zgar—80% [23].

There were fewer ponds in the steppe, and they grew more slowly. Only two of the 28 ponds created at the end of the 19<sup>th</sup> century on the Gnylii Yalanets River in 1924 were partially overgrown. Compared to

the forest steppe, there were significantly fewer ponds in Polissia. While 100 km<sup>2</sup> of forest-steppe accounted for 45.7 hectares of ponds, the southern areas of mixed coniferous and broad-leaved forests—only 10.6 hectares [22]. In the steppe and Polissia, ponds partially transformed only the floodplains of small rivers.

At the end of the 19<sup>th</sup> century, the construction of reservoirs on the rivers of Ukraine (Kaniv hydroelectric power station (HPS) in the Cherkasy region) begins. A little later (1912), the first reservoirs were formed on the Pivdennyi Buh, near the Tyvriv and Sutysky hydroelectric power stations. Later, 14 more hydroelectric power stations and reservoirs were built here. Since the 1930s, the construction of a cascade of reservoirs on the Dnipro began. In Ukraine, the Dnipro was destroyed by the six reservoirs. They turned the Dnipro's central, most productive part into a wetland area.

The area of anthropogenic water objects in industrial areas—Donbas, Kryvbas, Lviv–Volhynia basin, around large cities and nuclear power stations—is constantly increasing. Around Kryvyi Rih, 9 reservoirs with a total area of 9,340 hectares were created just for water supply of communal services; there are also 25 agricultural reservoirs [24]. Upon the end of the Second World War, in the process of rebuilding the economy (especially in the 1960s and 1970s), irrigation systems were actively developed in the southern steppes, and drainage systems were developed in the northern Polissia regions. The forest-steppe of Ukraine was partially subject to reclamation as well. As a result, an anthropogenic water network was made up of irrigation canals in the south of Ukraine, with drainage canals in the north. What did it lead to? From 1965 through 1990, the area of irrigated land in Ukraine increased almost four and a half times—from 540.3 thousand ha to 2.6 million ha, and the area of drained land—from 1.3 million ha to 3.3 million ha. During this period, the Kremenchuk, Kamianka, Kyiv, and Kaniv hydroelectric power stations were put into operation on the Dnipro, the North Crimean channel, the Dnipro–Kryvyi Rih, Dnipro–Donbas channels, the Dnipro–Mykolaiv aqueduct, and others were built. This made it possible to redistribute the water resources of Ukraine and provide them to the industrial regions of Dnipro, Kryvyi Rih, Kharkiv, Donbas, Crimea and create a powerful irrigation network for irrigating lands in arid regions of the Steppe. At the beginning of the third decade of the 21<sup>st</sup> century, the reclamation systems of Ukraine are partially or completely redistributed in the form of land shares. Most farms' reclamation equipment (irrigation systems and machines) have depreciated and are not renewed.

Out of once available 2.6 million ha irrigated soils, in the early 2020s, no more than 600,000 ha were irrigated. In the territory of almost half of the drainage systems, drainage channels are silted up. Soil flooding is observed. Part of the drained lands of Polissia

are not used as arable land and are overgrown with bushes, shrubs, and single trees. Since the beginning of the Russian Federation's military aggression against Ukraine, man-made water objects have been actively used for military purposes.

### Current state

*Small rivers.* Anthropogenization of the nature and landscapes of small river basins took place primarily in two ways: constructing an excessive number of ponds and the “clearing” and straightening of riverbeds with the simultaneous draining of waterlogged floodplains adjacent to them. Let us consider the example of the Silnytsia, a small river typical of right-bank Ukraine—the right tributary of the Pivdennyi Buh in Vinnytsia Oblast. Its length is 67 km, the catchment area is 830 km<sup>2</sup>, and it has 24 tributaries with a length of about 10 km. 63 ponds with an area from 0.2 to 250 ha were built in the Silnytsia basin. Among them, 24 are heavily silted and overgrown with swamp vegetation, 22 are drained and abandoned, and the rest of the ponds are used for fish breeding, household needs, and recreation. The ponds have completely overregulated the Silnytsia River and its tributaries, transforming its floodplain. The longitudinal profile of the river is step-like. The level of the new surface, created by silted ponds, has been raised compared to the natural floodplain, from 0.5 to 3 m. As a result, since the end of the 19<sup>th</sup> century, there have not been floods on the Silnytsia River; inundation, which is one of the most important features of floodplains, has gone; fertile alluvial sediments are concentrated in surface ponds, floodplain soils are buried under them. The average annual water temperature is 0.5–0.7°C higher than before the main construction of ponds in the 1950s. The landscape structure of the floodplain underwent drastic changes: meadow, woodland, and lowland swamp groups of tracts and oxbow lakes have been destroyed. The floodplain type of the terrain of the Silnytsia River has been transformed into a pond-floodplain by ponds.

*Medium-sized rivers.* Anthropogenization of medium-sized rivers and their basins, especially forest-steppe and mixed coniferous and broad-leaved forests, has been more radical than small rivers. The radical restructuring of the nature and landscapes of forest-steppe strips into forest-field, mixed coniferous and broad-leaved forests into forest pastures often culminated in forming water management drainage and irrigation-drainage landscape-engineering systems based on medium rivers. The middle river basins of the left bank of the Middle Dnipro region were particularly “unlucky” in the forest-field. Among them, the Trubizh River and its basin deserve special

consideration. In its natural state, the left tributary of the Dnipro—the Trubizh River—flowed out of the swamp near the village of Sukhyni in the Chernihiv region, flowed through the Dnipro lowland in Kyiv Oblast and in through 113 km flowed into the Dnipro. The valley of the Trubizh River is trough-shaped, up to 3.5 km wide; the riverbed is gently winding, and the floodplain is 500–600 m wide and swampy. The slope of the river is 0.26 m/km, there is no data in geographic encyclopaedias about the width (approximately 15 m) and depth of the Trubizh River in its natural state. This is not surprising.

Natural, historical, and social developments that took place during the respective periods (late 19<sup>th</sup>—early 20<sup>th</sup> century, the 1950s—1980s) contributed to the creation of the Trubizh water management landscape and the technical system, one of the most powerful in Ukraine. As a result of its operation, 37,600 ha were reclaimed in the basin of the Trubizh River. The above area included 28,300 ha in the Trubizh floodplain, 4,200 ha of the Nedra River, and 5,100 ha of the Karan River. Drainage and moistening were carried out using open canals with a total length of 1,238 km and closed drainage with an area of 12.5 thousand hectares. 732 hectares of the territory were under irrigation. The system's structure comprised 1,125 different hydrotechnical buildings, including 827 regulating locks, 19 of which were on the main channel. Its length was 216 km. The water balance deficit (3.3 million m<sup>3</sup> of water) was covered by spilling water into the headwaters of the Trubizh main channel from the Desna River. With the help of four pumping stations having a capacity of 6.0 m<sup>3</sup>/s, water was supplied to the anti-river by the river-bed of the Oster (43.3 km) to the village of Danivka, and then along the 12 km long derivation canal to the headwaters of the Trubizh River. To protect this river from being flooded by the waters of the Dnipro, a system of dams with a length of 10 km and a water pumping station with a productivity of 85 m<sup>3</sup>/s were built [18].

As of the early 2020s, the Trubizh water management drainage-humidification landscape-technical system is abandoned. Only some of its components are still in good working order. There are small (0.5–1.5 km) sections of canals and underground drainage systems (up to 300–420 ha), dams, and pump-

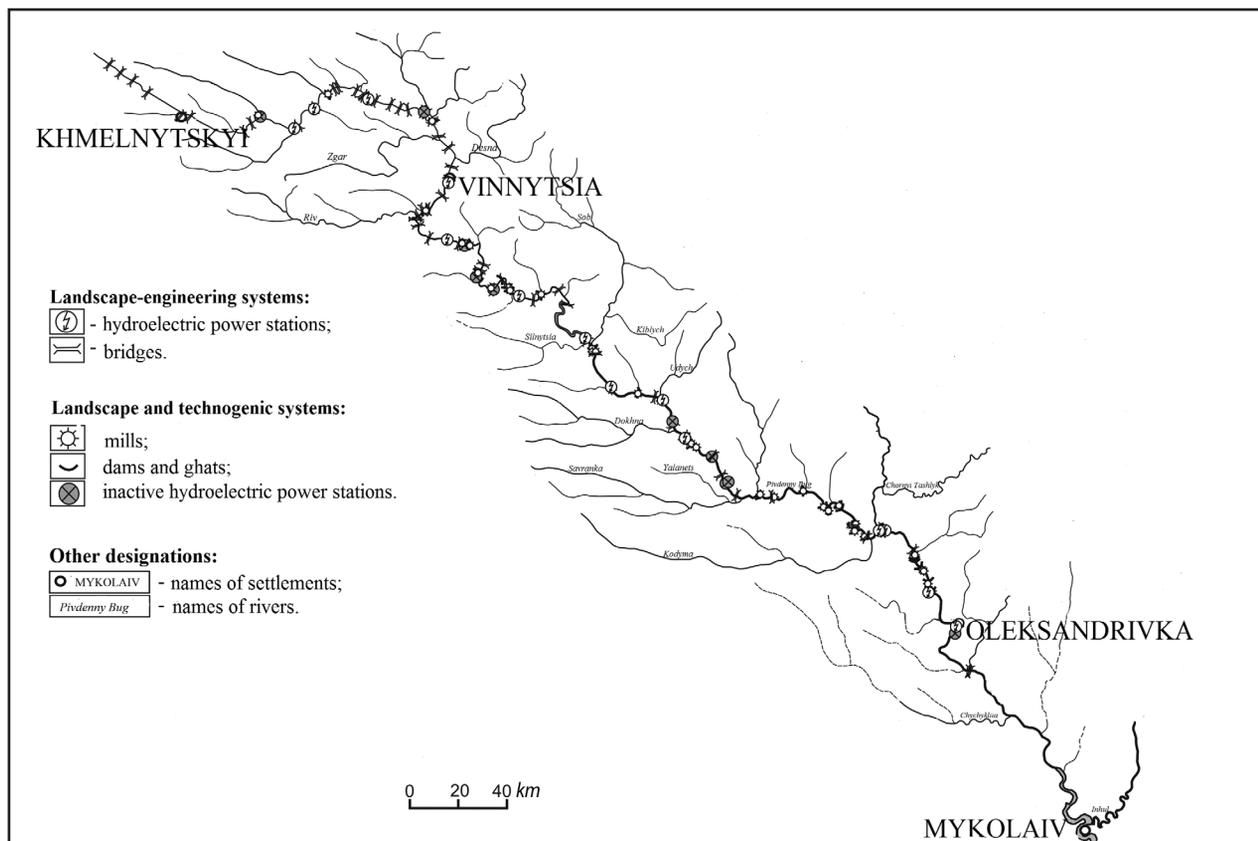


Fig. 1. Spatial arrangement of landscape and technical systems in the riverbed of the Pivdennyi Buh

ing stations that prevent waterlogging of reclamation areas. Overall, the Trubizh River has vanished. The water management landscape-engineering system created on its basis has also deteriorated. Other water management drainage-humidification landscape-engineering systems of the Dnipro basin and Ukraine are in a similar state. They include Berehiv (54,000 ha), Verkhnyoprypyat (25,100 ha), Romny (14,900 ha) and other systems.

**Big rivers.** In the second half of the 20<sup>th</sup> century, active anthropogenization and radical reconstruction of riverbeds (hydroelectric power stations, reservoirs) of Ukraine's large rivers—the Pivdennyi Buh, the Dniester, and the Dnipro—began.

**The Pivdennyi Buh River.** HPS dams regulate the Pivdennyi Buh riverbed, canals, ghyats, and reservoirs (Fig. 1). They are mainly concentrated in the middle part of the Pivdennyi Buh River, which is considered the most original in terms of natural conditions [6, 20]. Reservoirs do not form a cascade here. They are distant from each other and are at different developmental stages now. In their construction, the unique cascades of rapids in the Pivdennyi Buh River were partially transformed.

Significant regulation of the riverbed of the Pivdennyi Buh River has led to its deterioration. The analysis of changes in the river's water level in 2006–

2018 [12] made it possible to conclude that since 2015, the natural flow has been consistently smaller than the total volume of reservoirs and ponds in the basin. This led to significant siltation of the river-bed, an increase in water salinity, a significant weakening of the river to self-purification (slowing of the flow, flooding of the rapids), and a change in the landscape structure of the river-bed itself and, partially, the floodplain [1, 6, 9].

**The Dnipro.** Six reservoirs (Fig. 2) have completely destroyed the natural riverbeds of the Dnipro, its floodplain, and a significant part of the first above-floodplain terrace. The lower parts of the left-bank tributaries have been transformed into gradually overgrown, shallow marsh bays. Only two sections of the Dnipro Valley have retained their natural-anthropogenic character. They are downstream from the Kaniv HPS to the swampy headwaters of the Kremenchuk Reservoir and the section from the Kakhovka HPS to the confluence of the Dnipro with the Black Sea. After the barbaric disruption of the Kakhovka HPS by the rushists in 2023, the unique nature and landscapes of the Dnipro lowlands were destroyed.

A water-swamp area was formed after the construction of the cascade of reservoirs on the Dnipro. In the early 21<sup>st</sup> century, it has accumulated and regulated over 80% of the volume of all surface runoff in Ukraine.

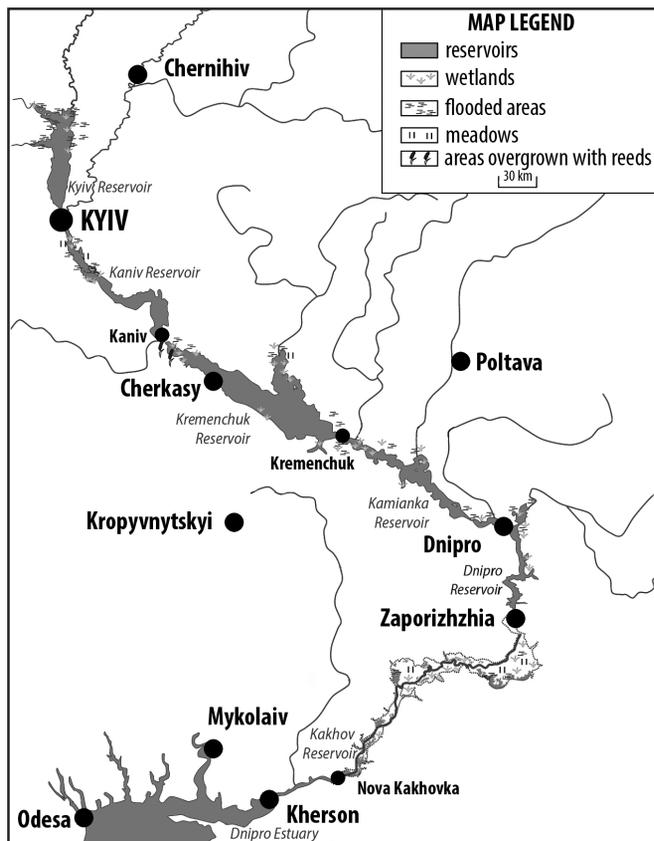


Fig. 2. The Dnipro aquatic and swamp district

This is Europe’s largest complex of hydraulic engineering buildings, and its development took almost half a century. The total volume of the cascade of reservoirs on the Dnipro is 43.7 km<sup>3</sup>, the useful volume is 18.6 km<sup>3</sup> of water, and the area of the water mirror is 2,469 km<sup>2</sup> [2, 10].

The Dnipro aquatic and swamp district is characterized in the following terms: 1) 709,900 hectares of land (their area is growing), 6,000 settlements, more than 10,000 cemeteries were flooded, 3 million people were relocated; 2) flooded territories with a depth of groundwater up to 2 m occupy 93.5 thousand ha, and shallow water with a depth of up to 2 m—133 thousand ha. The share of shallow waters in the water areas of reservoirs is 19.1%; 1.4 km<sup>3</sup> of water is regulated here, which is 13% of the useful summer volume [25]. Thus, the largest wetland landscapes in Europe have taken place of highly productive meadows and woods, agricultural landscape complexes of the floodplain, including those of the first, and partially, the second above-floodplain terraces of the Dnipro; 3) a new, extremely dynamic coastline with a length of more than 3,529 km was formed. About 40% of this coastline is swampy and covered with aquatic vegetation; the waves of reservoirs are actively destroying 1,329 km; 611 km are protected from processing and flooding by engineering buildings. The loss of land from coastal reclamation exceeded

25,000 ha. The most common types of transformed shores in the aqua-swamp area are abrasion-scaffold and abrasion-landslide. Before the construction of reservoirs, these types of banks were rare; 4) the Dnipro aqua-marsh region has developed its own climatic conditions, significantly affecting the surrounding territories. The decrease in summer and winter temperatures above the reservoirs and their “movement” by western air masses on the left bank of this area worsens the conditions for the development of flora and fauna, partly soils; 5) thousands of rivers and streams turned out to be below the level of the Dnipro reservoirs, which necessitated the construction of 34 permanently operating pumping stations. In the latter’s absence, mouths of small and medium-sized rivers have turned into shallow, often swampy, river bays.

The creation and functioning of reservoirs on the Dnipro caused hydrochemical changes in this river. The leveling of the intro-annual distribution of the dry residue and the shifting of the maximum and minimum dates to later dates were recorded. Foremost, such changes are characteristic of the lower course of the river. During 2012–2018, the lowest indicators of dry residue in the lower reaches of the Kyiv HPS were observed from June to July and in the lower part of the Dnipro—at the end of the year. A decrease in the content of nitrogen compounds, an increase in the concentration of inorganic phosphorus, and a decrease in the ratio between the total concentration of inorganic forms of nitrogen and phosphorus in the water downstream of the river were recorded. There is a significant fluctuation in the ratio between the total concentration of inorganic forms of nitrogen and phosphorus throughout the year. Thus, in the headwaters of the Kaniv reservoir, at the water intake of the Dnipro Water Supply Station, this indicator reached 30.0 in April and 5.0 in September and October. In the Kamianka reservoir near the village of Auly, the highest values (22.0) were recorded during April–May and the lowest (2.5)—during August–September [4].

Canals are a new anthropogenic “river network” of Ukraine, created mainly during the 20<sup>th</sup> century. Within mixed coniferous and broad-leaved forests and steppes, their length exceeds the length of riverbeds of the first and second order [22, 26]. The sources of the rivers originating in the marshy lowlands have largely been reclaimed. The canals are not deep. Their depth ranges from 1.0 m to 1.5 m. The width is 2.0 to 4.0 m. Their slopes are not fixed, and they are often washed away. It leads to silting and overgrowth of the canals. There is a particularly large number of drainage canals within Polissia. In the 1990s, the total

length of the canals, covering the area of 3.5 thousand hectares of agricultural land in the village of Myrne in Rivne Oblast, exceeded 80 km. It caused changes in the hydrological conditions locally and altered the watershed's landscape structure.

The main channels of southern Ukraine exceed small and sometimes medium-sized rivers in their measurements. The total length of the seven largest channels in Ukraine is more than 780 km. For example, the North Crimean Channel stretches for 400.4 km. The width of the area of action of the main channels reaches several kilometers. In the drainage areas, the hydrological conditions have changed significantly. The surface and underground runoff have been rebuilt (especially on irrigated lands and rice fields). Small filtration lakes and lowland swamps have been formed. The flora and fauna in the areas adjacent to the channels are changing. Overall, irrigation, drainage, drainage-irrigation canals, as well as transit canals, and various surface and underground water conduct make up the man-made "canal network" that is not inferior (in terms of length and importance) to the remnants of the convention-natural river network of Ukraine.

### Conclusions

Long-term, active, and versatile "economic" development of the natural hydrosphere has led to the complete anthropogenization of not only individual structures of rivers, lakes, swamps, and underground waters and the formation of a new anthropogenic hydrosphere. Geographers-naturalists, landscape scientists and hydrologists still tend to overlook this fact. "Classical" research into the given problem includes those primarily focusing on rivers, occasionally on natural lakes and reservoirs. The conclusions of such research are often either common knowledge or turn out to be irrelevant. The natural state of small and medium-sized rivers raises concerns. The only thing left of some rivers is their former direction; riverbeds and floodplains of large rivers have been completely rebuilt; the Dnipro valley has been transformed into an aqua-marsh area. After the destruction of the Kakhovka HPS dam, it became clear that our knowledge about Kakhovka Reservoir was insufficient: little was known except for the volume of water, its depth, and (partially) biota. That is why the consequences and processes taking place at the bottom of the former reservoir and the numerous artifacts found there are

River valleys, river-beds, lakes, estuaries, and marshes are natural habitats for flora and fauna and are to be protected under international treaties and regulations, including Council Directive 92/43/EEC on the Conservation of Natural Habitats and of wild fauna and flora. To accomplish this, the Emerald Network is being created in Ukraine. This network is the counterpart of the Natura 2000 network outside the EU countries. A significant part of its components are located in river valleys.

The anthropogenization of the hydrosphere in Ukraine led to diverse effects, including positive ones. For example, the creation of ponds and reservoirs resulted in the formation of wetlands that are the habitat of animals, in particular, rare species. Therefore, Kyiv, Kaniv, Kamianka, Kremenchuk, Dnipro reservoirs of the Dnipro River, the Ladyzhyn reservoir of the Pivdennyi Buh, the Pechenyg reservoir of the Siverskyi Donets, the ponds of the Zgar River (a tributary of the Pivdenny Bug) are areas of special environmental interest of the Emerald network, the basis of which is the anthropogenic hydrosphere of Ukraine.

surprising. The indeterminate future of this part of the Dnipro valley (as well as that of the entire Dnipro aqua-swamp area) arouses scientific interest.

In the early 21<sup>st</sup> century, we still lack fundamental research into the problem of once powerful (the 1960s—1990s), but currently neglected drainage (Polissia), drainage and irrigation (Forest-Steppe), and irrigation (Steppe) water management landscape-engineering systems. Nowadays, they represent the real state and characteristic features of the middle rivers of the anthropogenic hydrosphere of Ukraine, not the natural ones. This applies to many "lakes" of the Polissia, disappearing horizons of underground water, temporarily or completely dried up small rivers, shallow lakes, and swamps of the forest-steppe and steppe. Thousands of springs have dewatered; there is no water even in wells; some wells are already pumping water from deep horizons. All the above brings about the issue of the relevance of comprehensive investigations into the newly formed anthropogenic hydrosphere of Ukraine (not just its individual components). Promising directions include investigations into the modern hydrosphere, as well as litho- and atmosphere, pedo- and biosphere.

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**Стаття надійшла до редакції 18.07.2024**

**Для цитування [For citation]**

Denysyk, H. I., Yatsentiuk, Yu. V., Denysyk, B. H., Chyzh, O. P., & Voina, I. M. (2024). Modern Anthropogenic Hydrosphere of Ukraine. *Ukrainian Geographical Journal*. No. 4: 12–21. DOI: <https://doi.org/10.15407/ugz2024.04.012>

Дениsik Г. І., Яцентюк Ю. В., Дениsik Б. Г., Чиж О. П., Война І. М. Сучасна антропогенна гідро-сфера України. *Український географічний журнал*, № 4, 2024. С. 12–21. DOI: <https://doi.org/10.15407/ugz2024.04.012>