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**The centralized water supply of Kyiv is 150 years old (1872-2022)
- the importance of the Dnipro and Desna rivers**

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SUMMARY

The publication reflects the role of the Dnipro and Desna rivers in the water supply of Kyiv. In 2022, the Kyiv water supply system, built in 1872 with water intake from the Dnipro River, will be 150 years old. During this time, the role of the Dnipro changed - the share of groundwater in the water supply of the city grew, and subsequently the Desna River. In 1939, the Dnipro waterworks was built, which is still in operation today (design capacity 600 thousand m³/day). In 1961 the Desnianska waterworks was built (1080 thousand m³/day). The design capacity of the artesian water pipeline is 420 thousand m³/day.

In recent years, the average daily water supply in Kyiv is 700-720 thousand m³/day. The share of city water supply sources is as follows: Desna River - 66%; the Dnipro River - 25%; artesian waters - 9%. The highest specific indicator of the use of drinking water in Kyiv per capita was in 1991 - 588 l/day/person. Calculations show that in 2020 it decreased by 2.7 times. (219 l/day/person). An important role was played by the increase in tariffs for water supply.

The centralized water supply of the city also implies a centralized sewage disposal system. The Bortnitska aeration station, which built in 1965, receives 100% of the city's wastewater with the discharge of treated wastewater in the Dnipro River below Kyiv. The Dnipro and Desna rivers play an extraordinary role in the water supply of the capital. The Dnipro remains the hydrographic axis of Kyiv.



Introduction

In 2022, the Kyiv centralized water pipeline will be 150 years old. Currently, the construction of centralized water supply and sanitation systems is a common occurrence. However, for Kyiv in the second half of the 19th century and the construction and starting on March 1, 1872 of a centralized water supply system with water intake from the Dnipro River was an extraordinary event that brought the urban economy to a new technological level. The length of the pipeline at starting (only 23.3 km) was incomparable with the current length of the Kyiv water supply networks - about 4300 km (2022). Today, the world is facing water scarcity (Khilchevskiy et al., 2020; Khilchevskiy, Kurylo, et al. 2020). In Kyiv, for a century and a half, the role of the Dnipro River as a source of water supply changed - the share of groundwater increased, and subsequently the Desna River (the left tributary of the Dnipro). But it is indisputable that the Dnipro, together with the Desna, play an extraordinary role in providing the capital with high-quality centralized water supply. The Dnipro below Kyiv also receives sewage, helping the city to clean it. The role of the Dnipro in the formation of urban space is important. The river is a kind of hydrographic axis of the capital. The Dnipro and Desna are also important for Ukraine as a whole (Khilchevskiy, 2021).

The purpose of this study is assess the role of the Dnipro and Desna rivers as the largest sources of water supply in Kyiv.

Materials and research methods

The materials of the official websites of the Dniprovskaya and Desnianskaya waterworks, the Bortnytska aeration station, reports on the management of the private joint-stock company "Kyivvodokanal" (PJSC "Kyivwatercanal") for 2019 and 2020, materials of regime observations of waters of chemical composition of the unit of hydrometeorological of the State Emergency Service of Ukraine (Osadchyi et al., 2021), available works on this issue (Anakhov et al., 2018; Borysova, 2017; Petimko et al., 1997; Plichko et al., 2020).

Results

1. From the history of water supply and drainage in Kyiv

The following periods are distinguished in the history of water supply development in Kyiv (Petimko et al., 1997).

I period (5-16 centuries) - the sources of drinking water of Ancient Kyiv were rivers, streams, reservoirs, springs and wells.

II period (17th century - first half of the 19th century) - individual buildings on Podil were supplied with water from springs from the Kyiv mountains, which was supplied by wooden pipes laid underground.

III period (mid-19th century) - the appearance of local water supply systems in individual departments using mechanical means (steam pumps). 1843 - the first artesian well 103 m deep was drilled in the military hospital of the Kyiv fortress.

IV period (1872-1908) - On March 1, 1872, a centralized water supply was built for the central part of the city with water intake from the Dnipro and water purification on sand filters. 1895 - the first 2 artesian wells were drilled and connected to the water supply, 1896 - 7 more wells. The water supply of the city has become mixed (Dniprovskaya and Artesian Water) with a total volume of up to 20 thousand m³/day. 1894 - a centralized sewage system was built to divert wastewater to the filtration fields above Kyiv.

V period (1908-1939) - Kyiv received only artesian water in the amount of about 100 thousand m³/day. Due to an outbreak of cholera in 1907, the water intake from Dnipro River was closed. In 1909, the Lybidskyi sewer collector was built.

VI period (1939-1961) - in 1939, the Dniprovskaya water supply station was built (below Vyshgorod) with a capacity of about 100 thousand m³/day. The city again has a mixed water supply (surface and groundwater).

VII period (1961-1997) - in 1961, the first stage of the Desnianskaya water supply station was built (water intake from the Desna). The city received 3 sources of water supply: the Dnipro and Desna rivers and



artesian water. In 1964, the first block of the Bortnytska aeration station was built. Thus, in the mid-1960s, the general scheme of water supply and sanitation in Kyiv was formed and balanced, which has been preserved to this day (Fig. 1), despite a significant increase in the city's population (from 1.17 million people in 1961 to 2.97 million people in 2020).

VIII period (from 1997 to the present day) - in 1997, the first 17 pump-room complexes were built for groundwater; in 2022 - there were 203 of them (not all of them are active). Thus, decentralized water supply has been established next to the centralized.

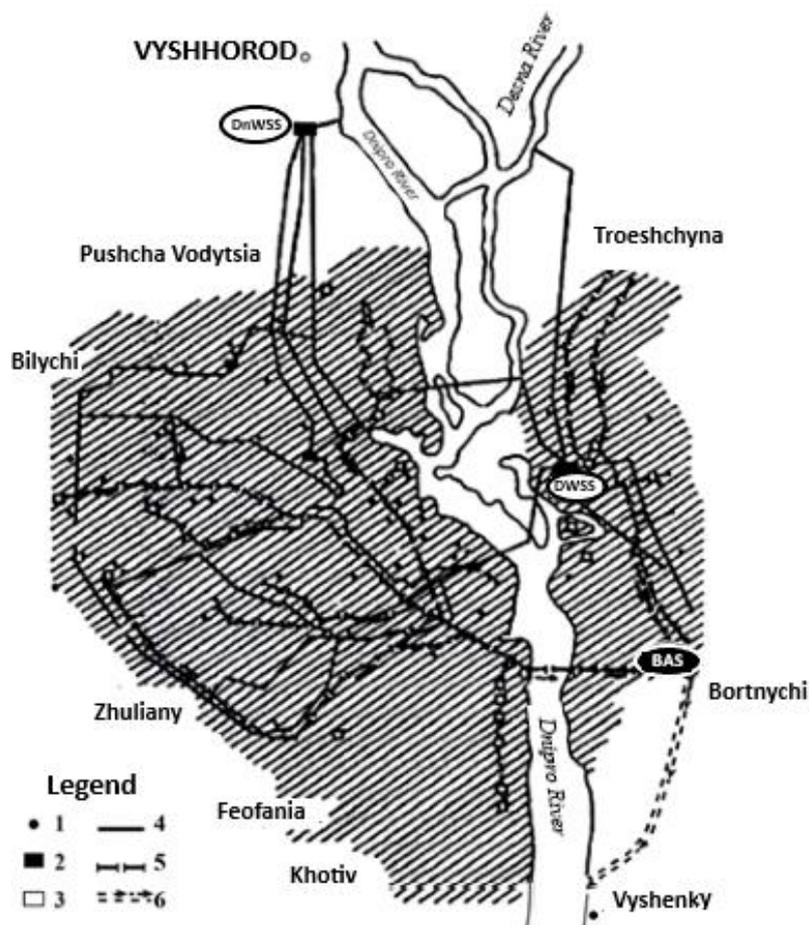


Figure 1 Map of the organization of water supply and drainage in Kyiv: 1 – artesian wells; 2 – water pumping stations; 3 – sewage pumping stations; 4 – water supply; 5 – sewer collectors; 6 – the main channel of sewage treatment from BAS; DnWSS – Dniprovska water supply station; DWSS – Desnianska water supply station; BAS – Bortnytska aeration station – wastewater treatment (map updated after source: Khilchevskiy, 1999)

During the 150-year period, the share of different water bodies in the water supply of Kyiv has changed (Table 1). Water supply 100% from the Dnipro River (1872-1907); 100% - groundwater (1908-1939); 28% - the Dnipro River and 72% - groundwater (1939-1960); 52% - the Dnipro River, 12% - the Desna River and 36% - groundwater (1961); 25% - the Dnipro River, 66% - the Desna River and 9% - groundwater (1961);

Of particular note is aspect - underground artesian water, which is produced by wells throughout the city, is not directly supplied to consumers. It mixes with water from surface sources (Dnipro or Desna) and in this form enters the water supply system. This is the so-called mixed water supply. In addition, groundwater has a slightly higher mineralization (400-600 mg/dm³) compared to river waters (300-320 mg/dm³).



Table 1 Changes in the share of the Dnipro, Desna and groundwater in the centralized water supply of Kyiv for different years (1872-2021 pp.), %

Years	Dnipro River	Desna River	Groundwater
1872-1907	100	–	–
1908-1939	–	–	100
1939-1960	28	–	72
1961	52	12	36
1965	36	38	26
1991	28	58	14
2021	25	66	9

2. Zoning of drinking water supply in Kyiv

There are three drinking water coverage areas: Desnianska water supply station, Dniprovska water supply station; mixed water supply (groundwater mixed with water from surface sources) - Fig. 2.

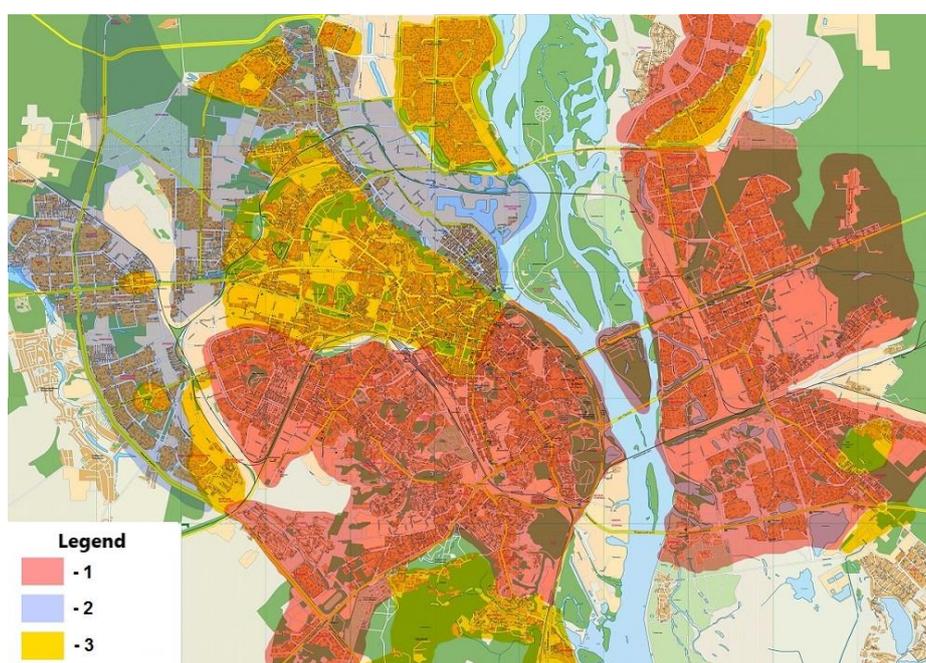


Figure 2 Drinking water supply on the territory of Kyiv. Coverage areas: 1 – Desnianska water supply station; 2 – Dniprovska water supply station; 3 – mixed water supply (groundwater mixed with surface water), 2022 (source: according to the data PJSC "Kyivwatercanal")

Desnianska WSS has the largest coverage area - the whole left bank, a significant part of the right bank - from the city center into the outskirts of Holosiivskiy district. Dniprovska water supply station supplies drinking water to the districts of Obolon, Podil, Vynohradar and parts of the streets along the ring road. Mixed water supply is present on both the left and right banks (in Fig. 2 highlighted in yellow).

3. Reducing water consumption in Kyiv

Comparison of indicators of water supply in Kyiv for 1961-2020 shows a tendency to reduce the city's water supply (Table 2). Indicators of drinking water supply to the centralized water supply network of Kyiv in 2018-2020 (660 thousand m³/day) is 2.4 times less than in 1991 (the year of maximum water supply) - 1 million 563 thousand m³/day.



Table 2 Drinking water supply to the Kyiv water supply network and discharges of wastewater to treatment facilities (1961-2020)

Year	Population, thous. persons	Supply of drinking water to the city, thous. m ³ /day	Specific water consumption, l/day/person	The share of water supply sources, %			Volume of waste water, thous. m ³ /day
				Dniprovska WSS	Desnianska WSS	Artesian Waters	
1961	1174	486	414	52	12	36	365
1965	1332	698	524	36	38	26	520
1991	2654	1563	588	28	58	14	1446
2018	2934	669	225	25	66	9	726
2019	2951	663	223	25	66	9	739
2020	2967	650	219	25	66	9	724

Conclusions

- 1) The water supply of Kyiv is inextricably linked with the Dnipro River, and later the Desna River. The share of water supply sources changed as follows. In 1961: 52% – Dniprovska water; 36% – groundwater; 12% – Desnianska. In 1965: 39% – Desnianska; 36% – Dniprovska; 25% – groundwater. In 2020: 66% – Desnianska; 25% – Dniprovska; 9% – groundwater.
- 2) An important factor in reducing water consumption in Kyiv has been the gradual increase in tariffs for water supply and sewerage services since the early 2000s.

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