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Study of the Hydrosystem and Environmental Monitoring of Water Quality of the Ponds and Water Sources in the National Dendrological Park "Sofiyivka" of the NAS of Ukraine

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ABSTRACT
At present, the problem of the availability of high-quality fresh water is urgent. The reservoirs from which water is extracted are running low. The amount of fresh water on the planet has decreased significantly in recent years. A big problem for the use of fresh water is its pollution. Groundwater remained relatively clean, but even when used, it needs to be controlled. Goal of research was the quality control of water from ponds and water sources in the National Dendrological Park (NDP) "Sofiyivka" of the National Academy of Sciences (NAS) of Ukraine in terms of physicochemical and bacteriological indicators and a study of the park's hydrosystem. When conducting research, potentiometric, gravimetric, titrimetric, colorimetric and spectrophotometric methods were used. The hydrosystem of the NDP "Sofiyivka" of the NAS of Ukraine, created during the period of its foundation, has basically retained its planning forms and all its artificial structures. The water system is an important environmental factor that contributes to the quality development of plants, and also has an aesthetic value. The analysis of the results of a study of the physicochemical and bacteriological composition of drinking water from the studied water catchments showed that the water is safe for consumption in terms of such indicators as the content of sulfates, nitrites, chlorides, but contains a significant amount of nitrates and has a high hardness, which can contribute to the development of a number of diseases. Long-term consumption of such water will have a negative impact on the human body. In all water samples from the capture, the growth of common coliforms in 100 cm^3 and the presence of *Escherichia coli* were found, which is dangerous when drinking unboiled water and can bring to intestinal infectious diseases. According to the obtained experimental results of the quality of the studied water samples from the Krasnostavsky, Upper and Lower ponds of the NDP "Sofiyivka" NAS of Ukraine, the general physical and chemical indicators fully comply with the established standards, but the results of studies of the ponds in terms of bacteriological indicators, namely the index of lactose-positive *E. coli* indicate their significant excess and non-compliance with the standards in the Krasnostavsky and Verkhny ponds by 48 and 12 times, respectively.

Keywords: water, pH value, total hardness, chlorides, sulfates, nitrates, nitrites.

INTRODUCTION

The amount of fresh water on the planet has decreased significantly in recent years. A big problem for the use of fresh water is its pollution. Groundwater remained relatively clean, but even when used, it needs to be controlled [Hryb et al., 1999; Snizhko, 2001]. To date, the violation of water quality standards has reached a critical level. This process can lead to the degradation of aquatic ecosystems, reducing the productivity of water reservoirs. That is why effective monitoring of water bodies should be carried out in order to identify sources of pollution and new, more advanced and efficient methods of water purification [Dzhyhyrey, 2000]. Providing the population with high-quality and safe for human health drinking water is guaranteed by the legislation of Ukraine [Law of Ukraine, 2017].

A special page in the history of the city of Uman was the creation of the world-famous "Sofiyivka" Park (1796–1802), the author of the project and the construction manager of which was the Polish military engineer Ludwik-Christian Metzel (1764–1848). The construction of the park was carried out in the valley of the river Bagno, later renamed the Kamianka. The determining conditions for choosing this area were its natural beauty, granite outcrops as a building material and the presence of water: the creation of the hydrosystem of the park on the Kamenka River had a dual purpose, aesthetic and utilitarian (park irrigation) [Kosenko et al., 1996; Kosenko, 2007].

The park was supplied with drinking water due to the presence of underground water outlets on its territory: they were formed as a result of the penetration of atmospheric precipitation and surface water into the depths of the earth, as well as due to the condensation of water vapor from the atmosphere. Groundwater, filling the pores of hard rocks, in granite form the so-called aquifers, and in the cracks is in the form of underground flows. Groundwater comes to the surface in the form of natural sources: descending, formed when free-flowing aquifers, lying on impervious foundations, release to the surface; ascending ones, formed when groundwater completely saturates the rocks between water-resistant layers, i.e., interstratal water comes with pressure to the surface of the earth in places where the impermeable rocks overlying it are disturbed. The water in such an aquifer is constantly in motion. The water level in such a source (pool, well) is above the level of the aquifer.

Distinctive features of groundwater are the constancy of temperature, the absence of suspended solids and color, and the relative ease of obtaining. Due to this, spring waters were widely used in the past for drinking water supply. The use of water with physico-chemical parameters deviating from acceptable standards has a negative effect on human health and can cause a number of diseases. It directly affects the rate of chemical reactions, the corrosiveness of the liquid and the degree of toxicity of pollutants [Okhrimenko et al., 2011; Rychak & Chepurna 2012].

The most common water quality problem is its high hardness, which is caused by the total amount of dissolved alkaline earth metal ions (calcium Ca^{2+} and magnesium Mg^{2+} are usually taken into account). To a lesser extent, beryllium, strontium and barium affect the hardness — they belong to the heavy metals list, therefore they are separately normalized by more strict standards. Water oversaturated with calcium and magnesium ions has worse organoleptic characteristics, it negatively affects the digestive organs and skin, and the cardiovascular system suffers excessively from it. Continuous use of hard water can lead to joint diseases, the formation of stones in the kidneys and in the bile ducts [Lypovetska, 2016].

Chlorides are highly soluble and therefore present in all natural waters mainly in the form of calcium, magnesium and sodium salts. Their entry into the water is facilitated by the leaching of sodium chloride and other chlorine compounds from the rock layers of volcanic origin. Many chlorides enter the water with industrial and domestic wastewater [Okhrimenko & Gafiatullina, 2011].

Nitrates and nitrites are salts of nitric acid widely used as cheap and effective fertilizers. Directly from agricultural fields, they enter the soil and open water reservoirs. It is very important to control the content of nitrates in water in areas with agricultural fields. In such areas, nitrates can be found in water sources in large quantities [Rychak & Chepurna, 2012]. In natural reservoirs, the source of ammonium accumulation is the products of decomposition and vital activity of various organisms. Excess ammonium can give water a very unpleasant odor and taste. And long-term use of such water leads to a violation of the acid-base balance in the body [National Standard of Ukraine DSTU ISO 6107-1:2004 DSTU YISO 6107-9:2004].

Sanitary and microbiological control of the quality of drinking water establishes the degree of its epidemiological safety in accordance with the requirements. The main sanitary-indicative test of water pollution by intestinal secretions of warm-blooded organisms remains the bacteria of the *Escherichia coli* group. *E. coli* is a fecal contamination indicator regulated by European Union (EU) Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, on the change of thermotolerant bacteria [Order of the Ministry of Health of Ukraine, 2005].

An important problem of ponds is the quality of water and the conditions under which it is formed. This is a complex characteristic of the chemical composition of a reservoir, its physicochemical and biological indicators, which determine the possibility of using water for economic purposes [National Standard of Ukraine DSTU 7525:2014, 2015]. The assessment of water quality is based on three groups of indicators: physical – color, odor, transparency, the presence of suspended solids, turbidity, etc.; chemical – the content of oxygen, mineral and organic substances, dissolved gases, foreign matters of non-natural origin, the concentration of which exceeds the regulated standards (TLV); hydrobiological – development of phyto- and zooplankton, phyto- and zoobenthos, higher aquatic plants, saprobic index, intensity of photosynthesis and respiration of hydrobionts [Lypovetska, 2016].

The formation of the water quality in ponds is provided by a combination of hydrochemical, bacteriological, hydrological processes, the physiographic and hydrometeorological features of the region and the level of anthropogenic impact [Polishchuk, 1988; Snizhko, 2001]. The standard indicators used to evaluate surface waters include the oxygen index (the content of oxygen dissolved in water), permanganate (total) oxidizability (COD), toxicological indicators, the content of nitrogen in the form of ammonium ions, nitrates and nitrites, the concentration of heavy metals, pesticides, petrochemicals, phenols, etc. [Al'okhina et al., 2008].

Goal of research was the quality control of water from ponds and water sources in the National Dendrological Park (NDP) "Sofiyivka" of the National Academy of Sciences (NAS) of Ukraine in terms of physicochemical and bacteriological indicators and a study of the park's hydrosystem.

MATERIALS AND METHODS

When conducting research, potentiometric, gravimetric, titrimetric, colorimetric and spectrophotometric methods were used. Water samples were taken in accordance with DSTU ISO 5667-2:2003. Water Quality. Sampling. Part 2. Guidance on sampling technique [National Standard of Ukraine DSTU ISO 5667-2:2003, 2003]. Laboratory studies were carried out in accordance with the current DSTU. The evaluation of drinking water was carried out by comparing the obtained values of the studied indicators with the standards specified in the State Sanitary Rules and Regulations 2.2.417110 "Hygienic requirements for drinking water intended for human consumption" [State Sanitary Rules and Regulations 2.2.417116, 2019].

To determine nitrates in water, test strips were used, which made it possible to determine the content of nitrates at home. The operation of such strips is based on the colorimetric method of analysis. The strips were immersed in the tested water for a few seconds. Then, after 30 seconds, while the strips were stained, a visual examination was made. The resulting color was compared with the reference scale available on the package with the strips. This comparison makes it possible to quantify the content of nitrates. Determinations of Cl^-, F^-, NO_3^-, NH_4^+ ions were carried out on ionomers with corresponding ion-selective electrodes. The instruments were preliminarily calibrated using standard solutions with a known concentration [Zapolskyy, 2005].

Oxidizability was determined by the concentration of reducing agents contained in water. Oxidizability is usually expressed in milligrams of atomic oxygen per 1 liter of water, mgO/l. In this regard, oxidizability is also called chemical oxygen demand (COD) [Guiding normative document KND 211.1.4.023-95, 1995]. The determination of orthophosphates was based on the reaction with ammonium molybdate in an acidic medium [Bilchenko, 2007].

RESULTS AND DISCUSSION

The NDP "Sofiyivka" of the NAS of Ukraine is located in the city of Uman, Cherkasy region at an altitude of 170–265 m above sea level, has geographical coordinates 48°46' north latitude and 30°14' east longitude GMT [Rudenko et al., 2007 a; Rudenko et al., 2007 c].

A significant role in the processes of development and formation of landscapes of the Right-bank Forest-Steppe of Ukraine belongs to surface waters. The main water arteries are the Dnieper and the Southern Bug. The water of these rivers and their confluents is widely used in the national economy. Within the last 60 years, the level of groundwater has been tended towards a decrease, which has led to the drying up of water sources and, as a result, to the loss of a number of reservoirs [Rudenko et al., 2007b; Monke et al., 2001].

The cascades of ponds built in the NDP "Sofiyivka" of the NAS of Ukraine greatly affect the water regime of its soils and the microclimate of the park. The water system of the NDP "Sofiyivka" of the NAS of Ukraine, created during the period of its foundation, has retained mainly its planning forms and all artificial structures to this day. This is due to the fact that a durable stone (local granite) was used for its construction. There are no materials indicating that any significant work that has changed the originally created type of water system has been carried out [Kosarevskiy, 1951].

The water system plays a dual role in the park: it is an important environmental factor that contributes to the successful development of vegetation, and it has aesthetic significance. In order to provide water for the work of waterfalls, cascades and fountains during the summer period and at the same time to decorate the park with water spaces, four ponds (water reservoirs) were created. They are situated along the bed of the Kamianka River. The water retained by earthen dams formed ponds with a free contour of the banks; from the ponds, it gradually enters hydraulic structures of the park.

Two ponds – Viytivski and Krasnostavskyi (hereinafter referred to as a Pond I) are located outside the park, and two – Upper (also called Novostavskyi, Sweet or Magic Sea; hereinafter referred to as a Pond II) and Lower (Ionian Sea hereinafter referred to as a Pond III) – on its territory. The water spaces of the latter are included in the general architectural complex of the park. The Upper Pond is the largest compared to the others (its area is about 8.6 ha). The water in it, thanks to the Voitovsky and Krasnostavsky (its area is about 18 ha) ponds located above, is maintained at the same level throughout the summer, providing the same pressure for the normal operation of the park's hydraulic structures. All the hydraulic structures are located between the Upper and Lower its (area about 1.1 ha) ponds (Fig. 1) [Kosenko, 2007]. From the Upper Pond to the Lower Pond, water flows in four directions.

The first direction is a gravity-flowing underground water supply system that brings water to the "Snake" Fountain, situated on the Lower Pond, and to the interior of Calypso Grotto (Lion, or Thunder Grotto). In engineering and technical terms, this waterway is designed with such consideration as to bring purified water to the fountain and to the grotto, and at an extremely low speed.

To do this, the simplest method of water purification was used, which consisted in the fact that the water is first passed through a large grate that trapped floating objects only. Then the water enters a stone underground sump, the bottom of which has an inclination in the direction opposite to the flow of water. Freed from heavy particles, clarified water enters the well, in which smaller particles settle. From the well, purified water enters Calypso Grotto and through a cast-iron flange pipe (35 cm in diameter) to the fountain [Kosarevskiy, 1951; Kosenko, 1996].

To maintain water pressure when it exits to the Lower Pond, the diameter of the fountain head is reduced three times compared to the diameter of the pipe supplying water. Thus, the height difference (between the height of the water column of the fountain and the level of the Upper Pond) was reduced to 1.5–2.0 m. The construction of this waterway made it possible to decorate the area of the Lower Pond with a large fountain and create a sound effect in the interior of Calypso Grotto.

a) b)

Figure 1. The Upper Pond (a); the Lower Pond (b)

A cast-iron snake, from whose open mouth a fountain jets, was installed in the 50s of the 19th century. To Calypso Grotto, the water was brought in with the aim of arranging a small waterfall in the interior of the grotto and, most importantly, in order to get a sound effect. Hitting the wall of the grotto under strong natural pressure, the water makes a noise reminiscent of the roar of a lion (hence the name Lion Grotto).

The second direction – unlike the first direction, in which the entire waterway is closed and only the end points go out, the second direction's waterway is completely open to visitors. The water from the Upper Pond goes through the spillway to the Grotto of Thetis (the Grotto of Venus). Then the water falls along the vertical wall of the middle stage of the grotto (a semicircular arch in which is glazed with colored glass) onto a horizontal platform. Further, in its movement, it covers the interior of the grotto with a water curtain, in which a statue of the Medici Venus was placed on a granite pedestal. The grotto can only be reached by a dark corridor located in the dam. It is necessary to note the peculiar solution of the channel, the bottom of which is narrowed from the side of the pond and expanded from the opposite side (to ensure a calmer and smoother entry of water into the channel, its initial part is usually made wider). The water, flowing along the horizontal bottom of the canal, forms a thin horizontal layer upon exiting it and falls like an even transparent curtain onto the steps of the upper stage of the grotto. Spilled into the lake adjacent to the grotto, the water enters the bed of the Kamianka River, along which, from the Grotto of Thetis to the Valley of Giants, it forms small waterfalls, cascades and lakes, which is facilitated by the relief and stones [Kosenko, 2007].

The third direction is a gravity pressure water supply. The water from the Upper Pond is brought with the help of an underground metal pipe to the center of the pool located in the Pheasant Cage in the Elysian Fields park area. The water pressure on the head of the fountain is regulated with a faucet. The height of the water jet in the Pheasant Cage is maintained at the level of 2.0–4.0 m. Excess water in the basin is discharged by gravity into the bed of the Kamianka River.

The fourth direction – in terms of the number and complexity of hydraulic structures and the volume of discharged water, this direction is the greatest in the park. The waterway of the fourth direction can be divided into two sections. The first one includes the Amsterdam Lock with an area of 34.2 m^2, the underground river Acheron (the Styx) with 211 m long and the Acheron Lake (the Dead Lake) of an oval shape measuring 32×25 m. The underground Acheron River and the Acheron Lake have the functional purpose of passing water from the Upper Pond to the "Seven-Jet" fountain, to the water steps and to the Great Waterfall.

Due to the fact that the water from the sluice along the underground river flows unevenly, and a constant level is required for the normal operation of the waterfall and the fountain, the so-called Acheron Lake was created. It is a kind of reserve and evenly supplies these hydraulic structures with the water.

The construction of waterways in the second section (the fourth direction) pursued mainly decorative goals. The water flows from the Acheron Lake: through an underground pressure pipeline to the basin of the "Seven-Jet" fountain, and from here through a tunnel to the Lower Pond; along the granite steps of the canal curved in plan – to sheer cliffs, from which it is falls down the Great Waterfall into the Lower Pond too. The Great Waterfall is the largest among all other hydraulic structures of the park, both in height and in the amount of water discharged. It adorns the central square of the park. The presence of water in the area to the north of the Assembly Square led to the construction of a number of objects in the park, which to a certain extent determined its original sight.

Diana's Grotto was built in 1796–1800 on a stone ridge. The base of the grotto 5.6×4.5 m is carved in the rock, and the walls are built of roughly hewn granite blocks. In the center of the grotto, there is a source Diana's Mirror, which is a catchment facility for capturing ascending sources – this is a reservoir located above the place of the most intensive groundwater outlet. At the same time, a layer of loose soil that covered a layer of dense bedrock, through the cracks of which the water enters, was removed. The source is a rectangular pool 1.75×1.55 m in size and 1 m deep. Ventilation and lighting are provided by a hatch arranged in the ceiling of the grotto [Kosenko, 2007].

Since the catchment facility is a source of drinking water for the historical part of the park, the entrance to the grotto was closed for a long time for sanitary and hygienic reasons. In 1996, the entrance was repaired and redecorated with an elegant metal bars, making it easier to access the grotto for proper maintenance [Dymchyk, 2016]. The pure water of the basin of this grotto was brought through a stone pipeline to the source "The Hippocrene": a pedestal of the statue of the Bathing Venus. This construction is a square granite pedestal. At the beginning of the XIX century, an alabaster vase for flowers was installed on it, later – in 1851, it was replaced by the statue of the Bathing Venus. The water flows directly from the pedestal and fills a bronze half-cup decorated with figures of grass-snakes, that is why the source got its another name "The Grass-Snakes". The water overflows the edge of the bowl and flows through an underground channel into the Lower Pond of the park. Next to the pedestal, a metal pipe supplying water for drinking comes out of the stone wall.

Groundwater accumulating in the "Menagerie" valley is discharged by a stone pipeline into the Lower Pond. On the place of a water-folding booth built in 1885, in 1974 the "Silver Springs" was built, the water comes to the source from Diana's grotto. The water to the source "The Iron Pipe" comes from the central part of the park, from Diana's Grotto too. At the entrance from Sadova Street in 1838, a pool was built, from which water enters "The Iron Pipe" source through a metal pipe and flows into a granite vase.

Thus, all surface and underground waters are discharged in different directions into the Lower Pond, the constant water level in which is regulated by a shield gate located to the east of Flora Pavilion. The water discharged by this gate flows down the natural bed of the Kamianka parallel to the Main Alley from its eastern side.

A feature of the hydrosystem of the NDP "Sofiyivka" NAS of Ukraine is that it is perceived as an essential part of an integral architectural complex, being a logical element of the compositional solution of the park [Kosarevskiy, 1951]. It is necessary to maintain the quality of water in the sources of the NDP "Sofiyivka" in accordance with the requirements determined by sanitary regulations. As for the amount of the water entering the source Diana's Mirror, it is possible that as a result of the work carried out to improve the water balance of the Kamianka River, the fullness of the aquifers associated with it will slightly increase.

In 2017, the authors conducted express tests for the presence of nitrates in four water samples from the sources of the NDP "Sofiyivka": the water from the source Diana's Mirror; the water from the source "The Hippocrene"; the water from the source "Silver Springs"; the water from "The Iron Pipe" source. To determine the concentration of nitrates in the water, the authors compared the color of the test strip immersed in the water sample under study with the color samples of the control scale, chose the marker that was closest in color and looked at the nitrate content. As a result of the research, in all the studied samples, an excess of the content of nitrates from the TLV was found (threshold limit value – 50 mg/l). For a more precise analysis of the quality of drinking water from the sources of the NDP "Sofiyivka" NAS of Ukraine, laboratory studies of the water samples were carried out.

Laboratory studies were carried out in 2017–2022. The assessment of the quality of the drinking water was carried out by comparing the obtained values of the studied indicators with the standards specified in the State Sanitary Rules and Regulations 2.2.417110 "Hygienic requirements for drinking water intended for human consumption: state sanitary norms and rules" [State Sanitary Rules and Regulations 2.2.417110, 2019]. The normal pH of drinking water is between 6.5 and 8.5. As can be seen from the data in Table 1, the pH of the studied water samples is normal.

Optimal for humans is the consumption of water with a total hardness of 3–4 mmol/l.

Table 1. Physicochemical and bacteriological indicators of the quality of drinking water from the sources of the NDP "Sofiyivka" NAS of Ukraine (July, average 2017–2022)

Source	Indicator								
	pH	General hardness, mmol/l	Chlorides, mg/l	Sulphates, mg/l	Nitrates, mg/l	Nitrites, mg/l	Ammonium, mg/l	Nonspecific coliforms, CFU/100 cm^3	Presence of *E. Coli,* CFU/100 cm^3
Diana's Mirror	7.71	12.3	50.2	46.3	62.2	<0.002	<0.1	more than 1	reveal
The Hippocrene	7.42	12.2	51.0	60.4	69.7				
Silver Springs	7.43	12.5	53.1	50.8	60.6				
The Iron Pipe	7.52	11.5	55.0	57.3	64.2				
TLV	6.5–8.5	<10.0	<350.0	<500.0	<50.0	<3.3	<2.6	1	0

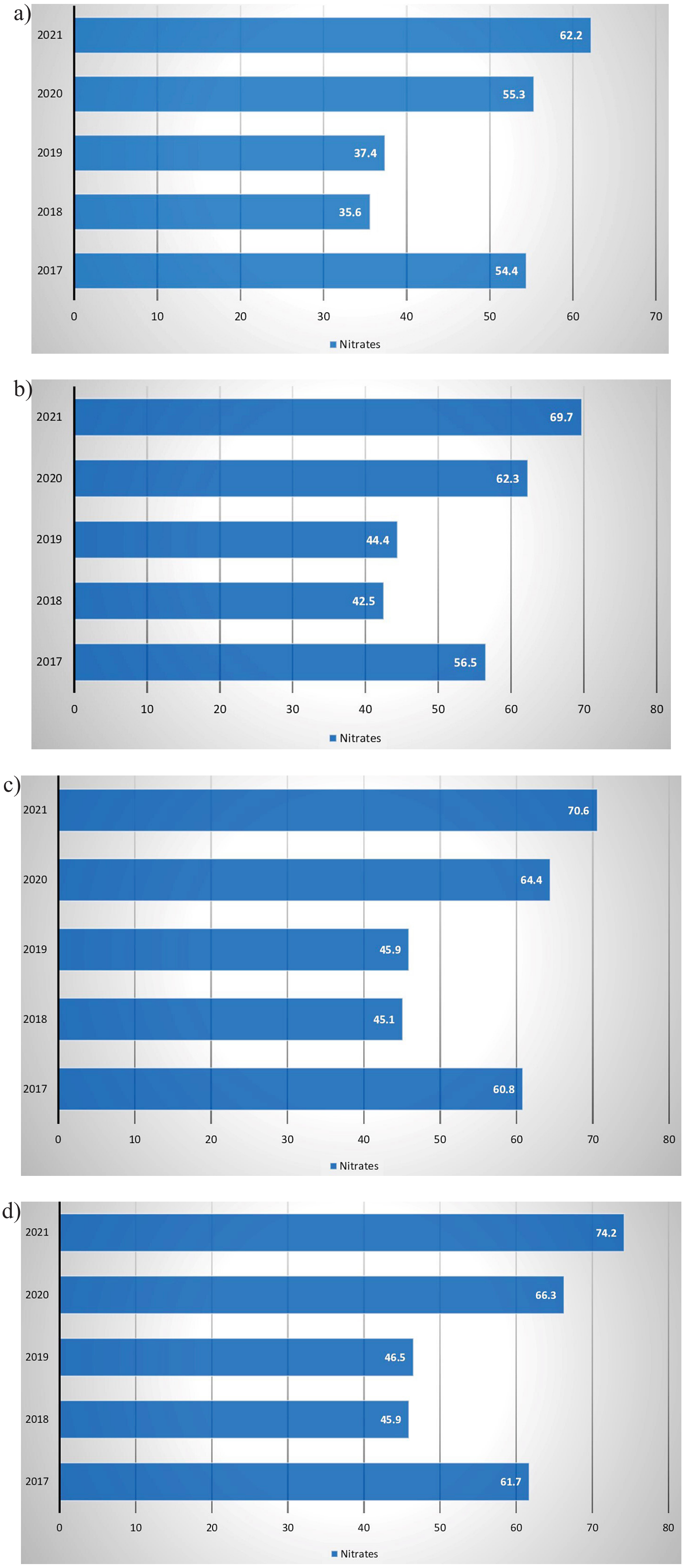

Figure 2. Concentration of nitrates (mg/l) in the water of sources of the NDP "Sofiyivka" NAS of Ukraine: (a) Diana'c Mirror, (b) The Hippocrene, (c) Silver Springs, (d) The Iron Pipe

The analysis showed that the water in all selected samples has a slightly higher hardness than the permissible norm. The lowest total hardness in the sample No. 4 (the water from "The Iron Pipe" source) is 11.5 mmol/l, the highest in the water of the sample No. 3 (the water from the "Silver Springs" source) is 12.5 mmol/l.

The safe content of chlorides in water should not exceed 350 mg/l. The analysis of the chloride content showed that its content in the source water samples is low and ranges from 50.2 mg/l to 55.0 mg/l – the characteristics of the chloride content of the studied sources did not show excess of the TLV. The content of sulfates in water should not exceed 500 mg/l; the characteristics of the content of sulfates as a result of the studies did not show excesses of the TLV.

According to the sanitary-chemical indicators, an excess of nitrate content by 10–19.7 mg/l was found in the water from the sources "The Hippocrene", "Silver Springs", Diana's Mirror and "The Iron Pipe". An increased content of nitrates in the studied samples can be observed as a result of the ingress of nitrogen-containing compounds into the water system with rainwater from agricultural lands. For many years, mineral fertilizers have been applied to the soil to increase the productivity of agricultural plants. During rains, part of the nitrogen-containing substances is carried out of the fields with water flows, and they enter the aquifer, that feeds the catchments.

In the selected samples of the spring water, nitrites are present in fairly low limits – less than 0.002 mg/l. The content of ammonium ions in the sources of the park under study is within the permissible norm (less than 1 mg/l). According to bacteriological indicators, the water in all the studied sources did not correspond to State Sanitary Rules and Regulations 2.2.417110 "Hygienic requirements for drinking water intended for human consumption: state sanitary norms and rules".

In order to investigate the ecological state of drinking water from the sources of the NDP "Sofiyivka", we compared the results of laboratory researches over five years. The comparison of the chemical indicators of the nitrate content was made (Fig. 2).

In 2017, 2020, 2021 the content of nitrates exceeded the standards. Analysis of the monitoring results indicates that in the drinking water of the studied sources the nitrate pollution was higher than the TLV by 4.4-24.2 mg/l. In the water samples taken from the sources Diana's Mirror and "The Hippocrene", a lower amount of nitrates was found than in the sources "Silver Springs" and "The Iron Pipe". This can be explained by the fact that, perhaps, the cast-iron pipes that were laid to the entrance to the park on Sadova Street were partially damaged by corrosion over many years of work, and this led to the ingress of ground- and wastewater into the hydrosystem.

The analysis of the results of a study of the physicochemical and bacteriological composition of the drinking water showed that the water from the sources of the NDP "Sofiyivka" NAS of Ukraine, which is often used by park visitors, is safe in terms of such indicators as the content of sulfates, nitrites, chlorides, but contains a significant amount of nitrates and has a high hardness, which can contribute to the development of diseases. Long-term consumption of such water will have a negative effect on a human body.

In all water samples from the sources, an excess of the established standards for the presence of nonspecific coliforms and the presence of *E. coli* were found; it is dangerous when drinking unboiled water and can lead to intestinal infectious diseases. The results of hydrochemical analysis to determine the cation-anion composition of the water from the ponds of the NDP "Sofiyivka" NAS of Ukraine, pH and total water hardness

Table 2. Examination of surface water quality in the ponds of the National Dendrological Park "Sofiyivka" (July, average 2020–2022)

Pond	Indicator										
	pH	General hardness, mmol/l	Sulphates, mg/l	Chlorides, mg/l	Fluorides, mg/l	Ammonium, mg/l	Nitrates, mg/l	Nitrites, mg/l	Phosphates, mg/l	Permanganate (total) oxidizability, COD, mgO/l	Dissolved oxygen, mgO/l
I	8.10	7.0	17.1	54.0	0.23	0.1	0.25	0.02	1.5	17.0	8.7
II	8.15	7.3	16.5	57.0	0.2	0.09	0.42	0.02	1.2	18.8	8.2
III	8.05	7.2	15.5	56.0	0.17	0.1	0.37	0.02	0.4	14.2	8.1
TLV	6.5–8.5	10.0	500.0	350	1.5	2.6	45.0	3.3	3.5	5.0	4.0

Table 3. The content of heavy metals in the water of the ponds of the NDP "Sofiyivka" (average 2020–2022), mg/ml

Pond	Chemical element			
	Ni	Pb	Cu	Zn
I	<0.1	0.27	0.029	0.08
II	<0.1	0.24	0.021	0.07
III	<0.1	0.021	0.017	0.05
TLV	0.1	0.03	1.0	0.1

over the years of the research (2020–2022) are shown in Table 2.

The total hardness of the water in the Krasnostavsky Pond (Pond I), the Upper Pond (Pond II) and the Lower Pond (Pond III) is 6.0–7.8 mmol/l, what characterizes the surface waters of these ponds as waters of medium hardness.

The COD indices are in the range of 13.7–19.0 mgO/l and significantly exceed the TLV (5.0 mgO/l). In 2022, the authors observe an excess of the limit permissible value of COD in experimental samples from the Pond I by 3.36 times, from the Pond II by 3.62 times and from the Pond III by 2.92 times. In authors' opinion, this is a consequence of water pollution by organic substances.

The concentration of biogenic ions (NO_2^-, NO_3^-) in the studied samples is less than TLV. The high content of dissolved oxygen (TLV 4.0 mgO/l) in the studied samples of surface waters (7.3–9.16 mgO/l) is typical for natural waters and indicates the sufficiency of self-purification processes. In terms of bacteriological indicators, the water in the Pond I and the Pond II does not meet the requirements: an excess of lactose-positive *E. coli* by 48 and 12 times, respectively, was found. The content of Ni, Pl, Cu, Zn in the ponds of the NDP "Sofiyivka" NAS of Ukraine was determined. According to the data of atomic absorption spectrophotometry, it was found that the content of heavy metals in the studied objects is within the ecological norm (Table 3).

Diana's Grotto, the source Diana's Mirror, the source "The Hippocrene", the source "Silver Springs" and the source "Iron Pipe" are protected in the complex of the National Dendrological Park "Sofiyivka" NAS of Ukraine. Initially created as structures of landscape architecture, Diana's Grotto, the source Diana's Mirror and the source "The Hippocrene" became the first link in the formation of the city's water supply system. Now, they have returned to their original function. Restoration work has been carried out on the objects, and now the main efforts should be made to maintain the objects in proper condition.

CONCLUSIONS

The obtained results of laboratory studies indicate the unsatisfactory state of drinking water of all the studied sources of the NDP "Sofiyivka" NAS of Ukraine in terms of nitrate content, hardness and bacteriological indicators. This water is not suitable for drinking. It is necessary to provide flushing and disinfection of the water networks of the sources, as well as to install information signs on the prohibition of the use of the water by park visitors from these park facilities.

According to the obtained results, the general physical and chemical indicators of the quality of the studied water samples from the ponds of the NDP "Sofiyivka" correspond to the sanitary and hygienic standards. In particular, the water from the ponds can be classified as neutral water with medium hardness. The high content of dissolved oxygen is characteristic of natural waters and indicates the sufficiency of self-purification processes. Exceeding the norm of chemical oxygen demand in the waters of the ponds of the NDP "Sofiyivka" NAS of Ukraine indicates a high content of reducing agents. The content of phosphates, nitrates, nitrites, sulfates, chlorides, ammonium ions generally does not exceed the TLV. The concentrations of heavy metals in the studied objects are within the normal range.

In terms of bacteriological indicators, the water in the Krasnostavsky Pond and the Upper Pond does not meet the requirements: an excess of lactose-positive *E. coli* by 48 and 12 times, respectively, was found.

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