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## RISK ASSESSMENT FOR POPULATION HEALTH IN USING DRINKING WATER IN KHARKIV

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**Abstract**
The problem of providing the Ukrainian population with high quality drinking water is becoming more and more complicated every year. Drinking low-quality water is an important contributor to human health, causes dangerous infectious diseases, and increases the overall incidence of the population. Determining the quality of drinking water in the Kharkiv city based on the assessment of the public health risk from drinking water consumption is a very urgent task. The paper presents an improved methodology for assessing the risk to the population's health from drinking water, which is a scientific novelty of the work. The analysis of providing the Kharkiv region with quality water resources and the current status of the water supply network is aimed to identify the main problems of water supply in the region. This paper first assesses the public health risk from drinking water in the Kharkiv city in order to prioritize the effective implementation of measures to improve the quality of drinking water and to reduce the incidence of population, so research studies have a practical importance.

**Keywords:** drinking water, water supply, sources, risk, population health, Kharkiv

Three independent sources of water supply are currently used for water supply in Kharkiv and in settlements of the region, two of which are at a considerable distance from the city itself [1]:

– Siverskyi Donets River with Pechenezh Reservoir (383 million $m^3$);

– Dnipro-Donbass Canal with Krasnopavlovsky Reservoir (about 410 million $m^3$);

– groundwater from artesian wells with depth of 80–800 m, located in the city and the region.

Services for consumers from centralized water supply and sewerage in the Kharkiv region are provided by 78 utility companies, most of them are at KP "Kharkivvodokanal" [1].

The main source of water supply is the Pechenezh Reservoir, whose water is the best in the region in terms of hydrobiological and salt composition. It is purified at the Donetsk Water Treatment Complex and is supplied by five main water pipelines with a diameter of 900-1600 mm with a total length of 161.2 km. The share in the total supply of drinking water is 440.7 thousand $m^3$/ day, or 75.4%.

The second independent source of water supply for Kharkiv is the Krasnopavlovsk reservoir, which receives sulfate water from the Dnieper-Donbass channel from the Dnieper-Donbas reservoir. Water treatment is also carried out at the Dnipro Water Treatment Complex, water is supplied to the city by two strands of main water pipes with a diameter of 1200 –1400 mm with a total length of 261.1 km. Their share in the total supply of drinking water is 134.09 thousand $m^3$/ day, or 22.9%.

The water quality of both sources is slightly different: Siverskyi Donets carries hydrocarbonate calcium waters, and Dnieper carries sulfate calcium. These waters are fresh, with mineralization up to 1 g/$dm^3$ and have an acceptable overall rigidity of 5 - 7 mmol/ $dm^3$.

However, in both sources there is a mismatch of drinking standards for a number of trace elements (organic and inorganic in nature), which is caused by the inevitable man-made pollution in the large catchment areas of these rivers.

A distinctive feature of the water quality from Severskyi Donets is systematically higher turbidity and suspended matter content, which is associated with the transfer of these substances to the river (especially during periods of snow and heavy rainfall). This is not seen in the Krasnopavlovsk reservoir, because the Dnieper water is defended before selection. Another important disadvantage of these surface water sources is the fluctuation of the water temperature and its flowering in the spring and summer.

The third independent source of water supply in Kharkiv is artesian wells. Today, their contribution to the urban water supply system is only 9.7 thousand $m^3$ or 1.7% [2].

The source of water supply to the population and economic sectors is the groundwater and surface water of the Siverskyi Donets and Dnieper River basins.

The supply of low-water regions of the region (Lozivsky, Pervomaisky, Kharkiv districts) and Kharkiv is provided by the transfer of water from the Krasnopavlovsky reservoir through the Dnieper-Donbass channel. The volume of the fence from the Krasnopavlovsky reservoir in 2019 amounted to 52.14 million $m^3$. The volume of approved groundwater reserves is 1 034,59 thousand $m^3$/day (377,6 million $m^3$ /year) and equals 26,7% of the forecast, amounting to 0,38 $m^3$ /day per inhabitant and 32,9 $m^3$ / day per 1 $km^2$ of area [3].

KP "Kharkivvodokanal" has one of the most developed water supply and distribution systems in Ukraine. The total length of water supply systems and water supply networks of the water supply and distribution system of KP "Kharkivvodokanal" is 2657.9 km, incl. main water supply systems has the length of 802.7

km (30.2%), water supply networks has the length of 1855.2 km (69.8%) [1].

2169.7 km of water supply systems and water supply networks are operated directly in Kharkiv, incl. water supply systems with the length of 314.5 km, water supply networks with the length of 1855.2 km. [1].

The length of technically worn water supply and water supply systems of the KP "Kharkivvodokanal" is 1401.3 km (52.72% of the total length), incl. main water supply lines −391.6 km (14.73%), water supply networks −1009.7 km (37.99%) [1]. The length of the pipelines of the system of KP "Kharkivvodokanal" in terms of lifetime is: up to 10 years−49.54 km (1.89%); under 20 years −136.73 km (5.20%); to 30 years −594,99 km (22,65%); under 40 years −452,0 km (17,20%); to 50 years −533,98 km (20,33%); up to 60 years −414.17 km (15.77%); up to 70 years −111.86 km (4.26%); over 70 years −333.90 km (12.70%) [1].

The amount of damage to the city's water supply and water supply networks tends to increase steadily. There is also a clear tendency in Kharkiv to increase the length of technically worn networks. Over the last 20 years, their length has increased by almost 40% [1].

Increasing the accident rate at water supply facilities, increasing the specific and unproductive costs of material and energy resources associated with the poor technical condition of facilities and equipment, adversely affects the quality of centralized water supply services and their cost [1].

The Kharkiv city alone can receive water about 180 thousand $m^3$ a day from the cretaceous deposits [4].

Investigation of spring water by physical and chemical indicators of rigidity and alkalinity is 1.5 −3 times lower than these indices in urban water supply; organoleptic characteristics are much better than in tap water; and by the number of chemical elements beneficial to human health, spring water is much better than tap water [4].

In many countries around the world, risk assessment methods for population health are used to determine the level of environmental hazards [5-8]. Hovewer, in our country there is only one officially approved method of calculating the magnitude of the risk to public health in the case of air pollution [7]. In Russia, a methodology for assessing the risk to public health from atmospheric air, surface water, soil, drinking water and foodstuffs is used [8], which is based on the US Environmental Protection Agency's (EPA USA) health risk concept. Adaptation of the American scientific approach to the determination of the risk to public health is a very important task. The technique of risk estimation to the health of the population from recreational water use is improved in the papers [9,10]. This scientific work also represents for the first time the scientific novelty with the technique of the risk estimation to the health of the population from the use of drinking water.

The risk assessment method for the health of the population provides for a separate determination of the carcinogenic risk and the hazard index.

Carcinogenic risk assessment is carried out in stages:

−generalization and analysis of all available information on harmful factors, features of their effect to the human body, exposure levels.

− calculations of individual carcinogenic risk for each substance entering the human body in the analyzed ways;

−calculations of the individual carcinogenic risk for each carcinogenic component of the test chemical mixture, as well as the total carcinogenic risk for the whole mixture.

−calculations of total carcinogenic risks for each of the analyzed routes of entry, as well as the total carcinogenic risk for all substances and all the analyzed routes of their entry into the body.

To evaluate the carcinogenic risk for each pollutant, risk indicators are calculated [8,9]:

$$CR = SF \cdot LADI, \tag{1}$$

where CR is the probability of contracting cancer, is immeasurable (usually expressed in units of 1: 1000000); SF−probability of getting cancer in case of single dose of LADI, 1 /mg/ kg • day.

The average daily dose of contamination with drinking water is calculated according to the formula [8,9]:

$$LADI = \frac{C_w \times V \times EF \times ED}{BW \times AT \times 365}, \tag{2}$$

where Cw is the concentration of the substance in drinking water, mg/l; V−the value of water consumption, l/day; for adults −2 l/day; for children −1 l/day, EF −frequency of exposure, days/year; 350 days / year; ED −duration of exposure, years; for adults −30 years; for children −6 years. BW −body weight, mg/kg; for adults −70 kg; for children −15 kg. AT −exposure period, years; for adults −30 years; for children −6 years; carcinogenic risk −70 years.

When assessing carcinogenic risk, it is advisable to focus on the classification of hazard levels presented in [8,9]. Acceptable risk is considered to be $10^{-4}$-$10^{-6}$.

The risk assessment of non-carcinogenic effects for individual substances is based on the calculation of the hazard coefficient according to the formula:

$$HQ = \frac{LADDI}{RfD}, \tag{3}$$

where HQ is the hazard ratio; RfD − reference (safe) dose, mg/kg.

The US surface and groundwater quality monitoring system is very different from the Ukrainian one, so some pollutants do not have reference dose information. Thus, the American methodology for assessing the risk to public health of drinking water needs to be adapted to apply it to the current system of state environmental monitoring.

In papers [8, 9] it was proposed to adapt the American methodology for assessing the risk to public health from recreational water use. In this article, we propose to determine the hazard index using the following formula for pollutants with the available reference dose information:

$$HQ = \frac{C_w}{MPC}, \quad (4)$$

where MPC is the maximum permissible concentration for drinking water, mg/l.

The risk characterization of non-carcinogenic effects upon combined and complex exposure to chemical compounds is performed on the basis of the hazard index (HI) calculation.

The hazard index for the conditions of simultaneous receipt of several substances in the same way (eg inhalation or oral) is calculated by the formula [8,9]:

$$HI = \Sigma HQ_i, \quad (5)$$

where HQi is the hazard coefficients for individual pollutants.

The papers [9,10] propose the classification of hazard levels according to the value of the hazard index. The hazard level is considered to be extremely high with a hazard index value ≥10.

Hazard indexes are calculated taking into account critical organs and systems that are adversely affected by the test substances. For contaminants that are not observed by the US monitoring system, we propose to determine, on the basis of the analysis of the literature, the critical organs and human systems that are affected by drinking water (Table 1).

Table 1

Probable impact of poor-quality drinking water (by individual pollutants) on human health

| The name of the substance | Organs and systems of the human body |
|---|---|
| mineralization | endocrine system |
| $BIA_5$ | endocrine system, digestive organs |
| HSC | endocrine system, digestive organs |
| Chlorides | central nervous system, liver, stomach |
| Sulphates | blood, endocrine system, the bone system |
| Magnesium | endocrine system, digestive organs |
| Calcium | kidneys |
| Ammonia nitrogen | anemia, various dermatitis |
| Nitrogen is nitric | blood |
| Nitrogen is nitrat | blood, cardiovascular system |
| Phosphates | the bone system |
| Iron | are mucous, skin, immunity |
| Copper | gastrointestinal tract, liver |
| Manganese | central nervous system, blood |
| Zinc | blood, endocrine system |
| Chrome | liver, kidneys, are mucous, gastrointestinal tract |
| Petroleum | kidneys |
| SPAR | respiratory system, skin |

On the basis of the improved methodology of risk assessment for public health, the level of danger of drinking water from the sources of Kharkiv was determined. Carcinogenic risk assessment has shown that it is acceptable.

The ranking of drinking water sources in Kharkiv by the magnitude of the hazard index for children and adults showed that the worst is the spring located in Yunost Park (Fig. 2.1). The likelihood of an increase in the incidence of drinking water from a source located in Yunost Park is presented in Fig.2.

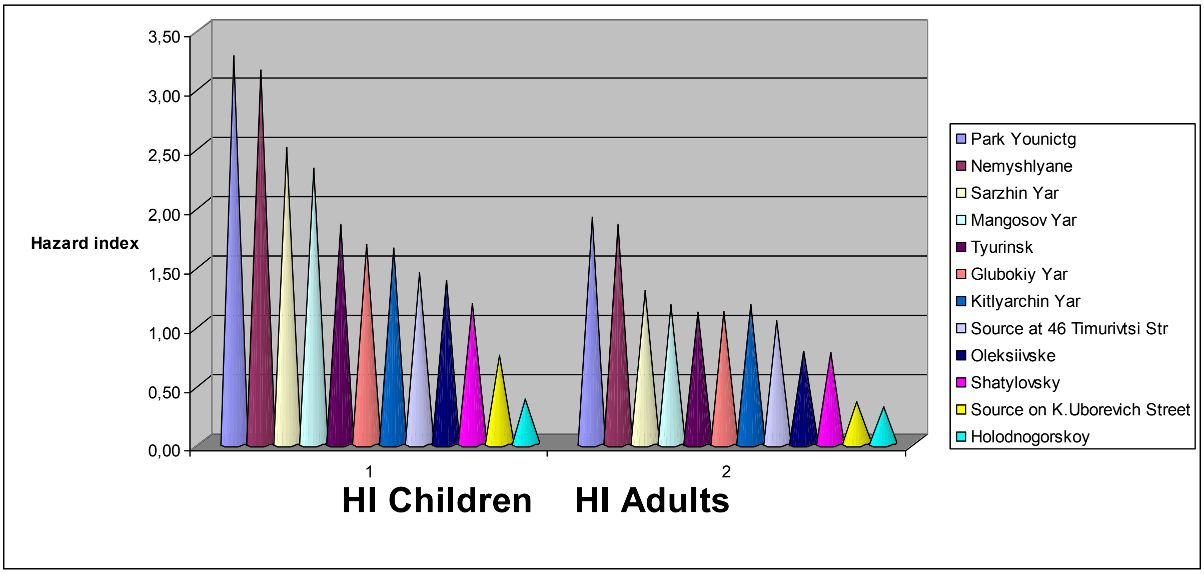


*Figure 1. Ranking of drinking water sources in Kharkiv by the magnitude of the hazard index*

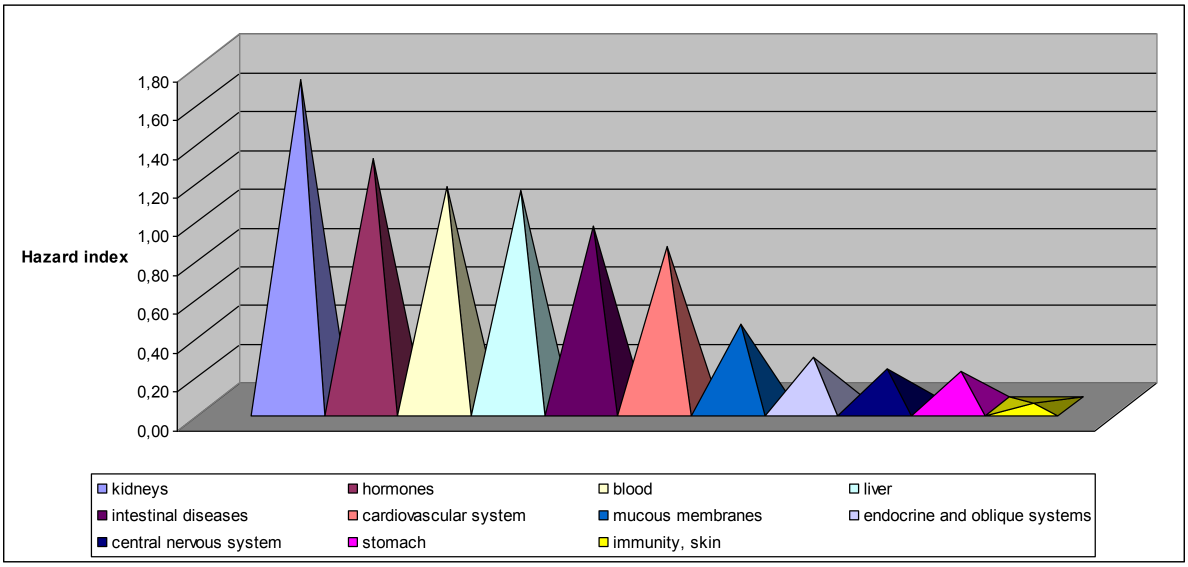


*Figure 2. The likelihood of an increase in the incidence of drinking water from the sources of Park Younictg in Kharkiv*

There are twenty consumer-equipped sources in the city. The most popular among the population is the Sarzhin Yar source which is a hydrological natural monument.

According to the classification of the hazard levels, there are only two sources that can be considered as low-risk sources: the source on the street. K. Uborevich and Kholodnogorskoe source. Drinking water from a source located in Park Younost is at the highest risk of increasing population morbidity.

The hazard index calculation showed that drinking water from a spring located in Yunost Park is most likely to cause kidney, blood and liver disease.

The water of the Kharkov water supply system by the content of organochlorine compounds during periods of sharp deterioration of its quality in surface water bodies (floods, "flowering" of water, etc.) does not meet the hygienic requirements and is a significant factor of carcinogenic and mutagenic risks for the health of the residents of Kharkiv region. This fact testifies to the urgent need to improve tap water disinfection technologies.

Not only water quality is affected by the choice of water supply system. The priority of choosing sources located in different corners of a metropolis determines the location of the source and the arrangement of the surrounding area.

Spring water plays an important role in the modern structure of drinking water supply for the city population in different countries. Sources can also be an additional component of drinking water supply during emergencies including man-made disasters and natural disasters.

The results of the analysis of the tap water offered to the residents of Kharkiv showed that the water of the city water pipes does not meet the requirements of DSanPiN2.2.4-171-10 "Hygienic requirements for drinking water intended for human consumption" [3] by many indicators.

The deterioration of drinking water quality causes an increase in the incidence of the population. Therefore, the public health risk assessment of drinking water consumption in Kharkiv is very relevant.

For the first time, the paper presents an advanced methodology for assessing the risk to public health from drinking water, which allows determining the level of danger and prioritizing risk management measures.

Determining the health risk from consuming contaminated drinking water allows us to predict the likelihood of an increase in morbidity, as well as to prioritize the implementation of the necessary environmental measures.

An assessment of the risk to human health of drinking water from popular sources in the Kharkiv city has shown that most of them require preventive measures.

For the first time, quantitative characterization of the dependence of harmful effects on the levels of exposure to specific pollutants is presented, which allows to estimate the probable threat to the health of the population, which represents the scientific novelty of the work.

Carcinogenic risk assessment of the population has shown that it is acceptable. However, an assessment of the drinking water hazard index in the Kharkiv city has shown the threat of an increase in overall morbidity, especially for the vulnerable.

The next step after population health risk assessment is risk management, is making the necessary management decisions to achieve the level of risk acceptability, taking into account the technological and economic capabilities of the most dangerous enterprises - environmental users to implement environmental measures.

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