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ORIGINAL ARTICLE

Ecological and hygienic assessment of drinking water quality of Kyiv Polissya

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The problem of providing the population with quality drinking water in conditions of intense anthropogenic pressure on the environment is actual. The need for clean water is especially acute in industrial regions and territories with decentralized water supply, including Kyiv Polissya. The paper presents the results of a study of the chemical composition of drinking water in the settlements of Kyiv-Sviatoshynskyi and Fastivskyi districts of Kyiv region. The level of natural and anthropogenic loads is characterized. The high level of groundwater pollution in the studied areas is due to their insufficient protection against vertical filtration of pollutants. Within the Kyiv region groundwater is almost everywhere unprotected. Hence, the sewage water of industrial entities pollutes water reservoirs with various ecotoxicants. Qualitative condition and level of drinking water pollution in residential areas in the region is generally characterized by the ratio of the number of examination in overrun of the approved standards of the MPC (Maximum permissible concentration) to the total number of examines performed. The analysis of this situation showed that the Kyiv`s region examined areas face the problem of bad quality groundwater composition. Overrun of the hygienic standard of water hardness and concentration of calcium ions and nitrates in it is established. Now, the unfavorable environmental situation in the region affects the population health`s and has a strong regional nature.

Currently, the unfavorable environmental situation in the region affects the health of the population and has a clear regional character. Most residents of some areas consume drinking water, which is an independent environmental station. Dangerous drinking water has created a set of social and health problems. Assessment of drinking water quality for its ecological and hygienic characteristics allows to assess the possibility of impact on human health.

Keywords: Ecological condition of territories, Ecotoxicants, Ecological indicators, Ecological and hygienic indicators, Well, Quality of drinking water, Morbidity of the population.

Introduction

Following the results of the XX century, the population came to the conclusion that the threat to human existence lies not so much in the nuclear danger, but in a catastrophic environmental situation. One of the most serious concerns is the shortage of drinking water, its qualitative changes, non-compliance with sanitary and hygienic requirements, as well as the serious consequences of the consumption of bad quality drinking water for human health.

The process of obtaining and supplying conditioned drinking water to the population depends on a number of factors, the main of which are: the state of water supply sources and decentralized drinking water systems, sanitary condition of water supply networks, and the level of laboratory quality control at all stages of its preparation and supply (MacDonald and Tippett, 2020).

Groundwater is an important source of decentralized water supply for 80% of rural residents of Ukraine (up to 80% of settlements). In contradistinction to surface, the latter are more protected from anthropogenic pollution due to the soil. However, the problem is that currently soils are so polluted that they do not perform their sorption function and, accordingly, pollutants enter groundwater. Also, the latter are not protected by water-resistant rocks, and their nutrition occurs as a result of filtration of precipitation through a small (1.5-2 m thick) layer of soil, they are the most vulnerable. That`s why the examination of water quality by chemical indicators is now becoming especially relevant. In addition, today it is no longer necessary to prove the role of water in human life: the quality of human health, the level of their sanitary and epidemiological well-being, the degree of comfort and, consequently, the social stability of society in general (Shumygai, 2012).

The notion that drinking water can cause harm that adversely affects human health dates back to ancient times. So, in the XIX century Louis Pasteur claimed that "a person drinks up to 90% of his illness", so it can be attributed to the factor of constant chronic exposure. Contaminated water is one of the main causes of morbidity, especially among children. Today, more than 1 billion people in the world consume water that does not meet sanitary standards. According to scientists, up to 10 million people die every year due to polluted water (Doroguntsov et al., 2006; Kotlyar, 2002).

Therefore, the purpose of this examination is to assess the quality of drinking water sources of decentralized water supply by chemical indicators in certain administrative districts of Kyiv region, and also to identify the drinking water quality impact`s on human health.

Materials and Methods

Water quality largely depends on its ionic composition. In general, for the vast majority of natural waters, the total salt content is quite accurately determined by cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^-, SO_4^{2-}, Cl^-). Other ions are usually present in small quantities, but can significantly affect the properties and quality of water.

The analysis findings of the ionic composition of water can be conveniently represented graphically (Fig. 1).

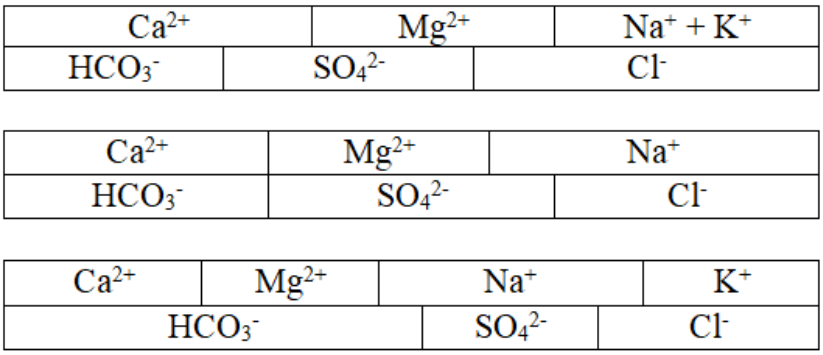

Fig. 1. Diagram of the hypothetical composition of salts in water.

The anions in the diagram are arranged in ascending order of their acidic properties. The location of cations is determined by the order in which they will form sparingly soluble compounds with a gradual increase in pH (Guidelines for Drinking-water, 2011; Alekseev, 2009).

Monitoring was conducted during 2019-2020 in wells of Kyiv-Sviatoshynskyi and Fastivskyi districts of Kyiv Polissya to assess the salt composition of drinking water. According to the approved requirements and standards, hydrochemical analysis was performed in selected samples by various methods. Also groundwater quality is assessed by chemical, physical and microbiological characteristics, which are regulated by state sanitary norms and rules (Hygienic Requirements for Drinking Water, 2012).

Morbidity of the population can be considered the most sensitive indicator that characterizes the state of human health. This is a quantitative indicator of the spread of the disease, which is determined by the number of cases (absolute) or the number of cases per 100 thousand population (relative). Literature and Internet sources, as well as statistical data of the regional information-analytical center of statistics of the Kyiv regional council were used to achieve the set goal of morbidity.

Results and Discussion

An examination of the chemical composition of drinking water found that the population of Kyiv region consumes highly mineralized water (Table 1).

Table 1. The results of the analysis of chemical groundwater examinations.

Indicator	Measured value in wells				MPC in drinking water
	K.-Svyatoshinsky district		Fastivskyi district		
	Boyarka town	Gatne village	GDR "Velykosnitynske"	Kozhanka township	
pH	7.28 ± 0.05	7.32 ± 0.05	7.51 ± 0.05	7.78 ± 0.05	6.5-8.5
Dry residue, mg/dm^3	428 ± 3.5	360 ± 3.3	700 ± 14.3	250 ± 5.1	≤ 1500
Smells and flavour, balls	0-1	0-1	2-3	2-3	≤ 3
BIA_5, mg/dm^3	1.32 ± 0.01	2.16 ± 0.08	2.82 ± 0.07	2.53 ± 0.03	3
HSC, mg·O/dm^3	2.52 ± 1.09	0.14 ± 0.02	48.64 ± 4.86	19.39 ± 1.94	≤ 5
General hardness, mg-eq/dm^3	8.13 ± 0.15	5.24 ± 0.39	20.84 ± 0.42	7.85 ± 0.06	≤ 10
Fe^{3+}, mg/dm^3	0.03 ± 0.01	0.04 ± 0.01	0.13 ± 0.03	0.09 ± 0.02	≤ 1.0
Ca^{2+}, mg/dm^3	110.02 ± 2.01	76.15 ± 1.15	40.24 ± 0,80	14.72 ± 0.29	25-75
Mg^{2+}, mg/dm^3	30.16 ± 0.54	16.82 ± 0.16	216.51 ± 6.50	81.82 ± 2.45	10-80
NH_4^+, mg/dm^3	0.06 ± 0.01	0.005 ± 0.01	0.22 ± 0.01	0.29 ± 0.01	≤ 2.6
NO_3^-, mg/dm^3	23.9 ± 0.13	11.66 ± 1.21	76.32 ± 3.05	47.51 ± 1.9	≤ 50,0
Cl^-, mg/dm^3	20.53 ± 2.65	26.78 ± 2.24	212.82 ± 4.26	72.12 ± 1.44	≤ 350
SO_4^{2-}, mg/dm^3	91.43 ± 2.47	75.43 ± 1.87	238.75 ± 7.16	91.16 ± 2.73	≤ 500
F^-, mg/dm^3	0.039 ± 0.01	0,036 ± 0,01	0.12 ± 0.01	0.23 ± 0.02	0.7-1.0

In particular, the total mineralization of drinking water in Fastiv district (GDR "Velykosnitynske") exceeds the hygienic regulations and reaches 1512.99 mg/dm^3. Water mineralization is associated with an important organoleptic criterion-total hardness, ie the set of properties due to the content of alkaline earth metals (calcium and magnesium). The value of total hardness varies in the range of 5.3-20.8 mg-eq/dm^3, at sanitary norms it should not exceed 7 mg-eq/dm^3 (Hygienic Requirements for Drinking Water, 2012). Of the four settlements we examined, only in the village Gatne (K.-Sviatoshynskyi district) hardness of drinking water meets the recommended standard, in others it exceeds the specified standard.

Comparison of the concentration of calcium and magnesium cations shows that of the drinking water hardness in the settlements of K.-Sviatoshynskyi district is mainly due to calcium cations, while the concentration of magnesium cations is small and in most samples reaches 10-20% of the total content of these ions in water. Exceeding the maximum concentration limit or approaching it in terms of magnesium content is observed in two water samples of Fastiv district, but the most dangerous in this respect is the water of the first well (216 mg/dm^3), which is unsatisfactory for human physiological needs. Magnesium ions enter the water due to the interaction of carbon dioxide with minerals and other processes of dissolution and chemical weathering of rocks, as well as microbiological processes.

There is a very acute problem of nitrate pollution of well waters in the Kyiv region, which occurs due to the application of mineral and organic fertilizers, erosion of household landfills by precipitation, etc. This ecological situation can be observed in VP "Velykosnitynske", the territory of which specializes in growing crops and has a developed livestock industry.

Our research has established that the water content of wells in K.-Sviatoshynskyi district is weakly mineralized. Regarding the physiological value of the examined sources of drinking water supply, it should be remembered that almost the entire territory of Ukraine belongs to the biogeochemical province with low fluoride content in groundwater, as recorded by the authors. Thus, the conducted research allows to state that drinking water in the examined districts of Kyiv region does not fully meet the requirements of the existing in Ukraine standard of drinking water quality. The main pollutants are organic compounds, nitrates. The concentration of water in the wells of the examined areas is either at the level of the MPC, or exceeds it, which indicates a long-standing, long-term pollution of nearby aquifers. These waters cannot be considered physiologically complete either, as they lack fluoride. The problem is that the depth of most wells reaches 1.5-6 m. That is, they feed on the waters of surface horizons, which have a much worse bacterial characteristics compared to underground. Another cause of bacterial contamination of water is errors in the architectural planning of estates and farms, which are in close proximity to sources of drinking water. Therefore, it is necessary to repair these wells and purify the water in them at least once a year, as the value of clean water for humans health is difficult to overestimate.

There is no doubt in society today that health is directly linked to the environment. Currently, the risk to human health from the consumption of bad quality drinking water is very high, as the state of decentralized water supply in Ukraine and the quality of drinking water remain unsatisfactory, and in some regions-critical. Water, in contact with many medium, dissolves a huge amount of chemicals, including organic and inorganic. Some of them themselves may not be very harmful to the body, but become harmful in contact with others. They can be useful, but in combination with something, cause great harm. The same in water: there are many microorganisms that can cause many diseases. It is known that the entry of substances into the body together with drinking water, in concentrations above the maximum allowable, can cause irreversible changes in the most important systems of human life (Table 2) (Schmoll et al., 2006; Goncharuk et al., 2004).

Table 2. The impact of the main components of the chemical composition of drinking water on human health (Shumygai, 2012).

Water composition component`s	**Necessary daily needs, grams**	**MPC mg/dm^3**	**Impact on the state of health of the population with excessive and insufficient intake and exceeding the MPC**
Calcium	0.4-0.7	3.5	*Disadvantage*-an increase in the number of deaths in the case of cardiovascular disease (hereinafter-CVD), weight gain rickets, dysfunction of the heart muscle and blood clotting processes. *Excess*-urolithiasis, disorders of water-salt metabolism, early deposition of lime on the cartilage of bones in children, slowing of skeletal growth.
Magnesium	0.2-0.3	20	*Disadvantage*-sudden death of infants, weight gain and adverse events KVN, neuro-muscular and psychiatric symptoms, tachycardia and fibrillation of the heart muscle, hypomagnesemia. *Excess*-the possibility of developing syndromes of respiratory paralysis and heart block, gastrointestinal tract.
Fluorine	1.3-1.9	1.5	*Disadvantage*-caries. *Excess*-fluorosis, polyneuritis, osteosclerotic bone changes, arterial hypotension.
Sodium	-	200	Hypertension

Nitrates,	-	45	Gastric cancer, methemoglobinemia
nitrites	-	33	
Iron	-	0.3	Allergic reactions, blood diseases
Sulfates	-	500	Diarrhea, increased hypoacid status
Chlorides	-	350	Hypertension

But it is also bad when the concentration of the required element is less than it is necessary for the normal functioning of the body. According to the famous medieval scientist Paracelsus, everything is a poison, everything is medicine-it all depends on the dose. Often, even a slight excess of a certain substance causes illness and death (Khoruzhiy and Khomutetskaya, 1997). Hence, it is important to know the physiological properties of the most common compounds. If contact with such harmful substances is constant, then, of course, the risk of poisoning increases. In addition, the body's immunity is weakened, the risk of chronic diseases increases.

Analysis of literature sources (Shumigay et al., 2021; Shumigay, 2015; Shovkun, 2004; Okorokov, 2001) shows that the chemical composition of drinking water can affect the occurrence and course of diseases caused by the entry into the human body of a number of trace elements. The content of the latter in water significantly affects human health, leading to the emergence of specific diseases. Thus, being in the blood, nitrates directly act on blood vessels, dilate them, causing a decrease in blood pressure. Their excess is the cause of eczema, tooth decay, damage to the heart, kidneys, liver, and constant intoxication of the human body leads to metabolic disorders and cancer. Nitrate poisoning is also dangerous because they tend to accumulate in the body, and the effects of severe poisoning can last more than a year, causing impaired associative abilities, impaired memory and muscle strength, general weakness, headache, dizziness and fatigue.

Also (A Review of Human Carcinogens..., 2012; Guidelines for Drinking-water Quality, 2011) it is believed that cancer (cancer of the colon, kidneys, liver and bladder) may be associated with the intake of organochlorine carcinogens with drinking water.

According to the analysis of the dynamics of morbidity of the population for the period from 2010 to 2017 within the Kyiv region, a tendency to increase the incidence rate was established (Fig. 2). In addition, epidemiological examines have shown significant increases in gastric cancer mortality in people living in areas with high levels of nitrates/nitrites in drinking water.

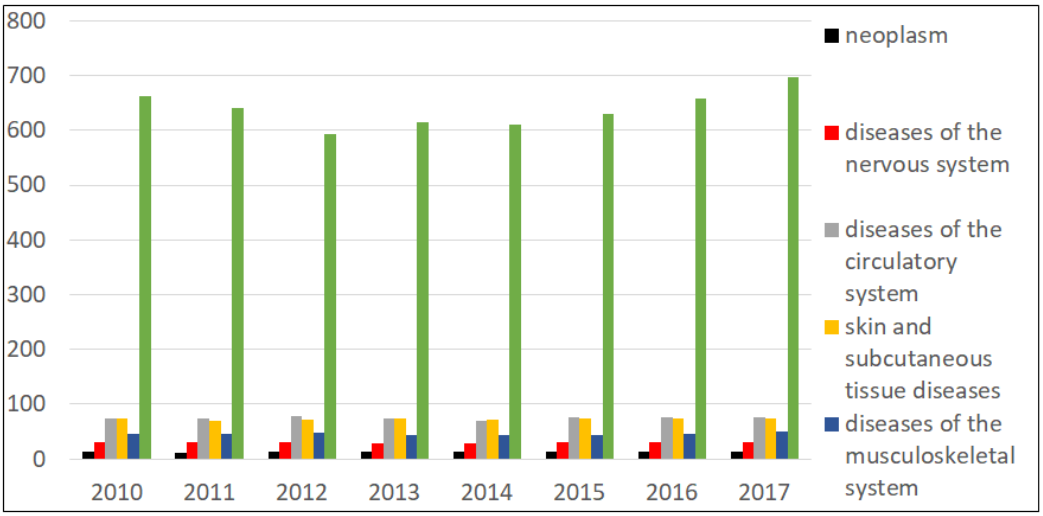

Fig. 2. Number of registered cases, thousand.

It should be noted that water pollution at excessive concentrations of nitrates causes water-nitrate methemoglobinemia, especially in infants who are given formulas made using such water. In this disease, nitrates that enter the baby's body are converted into nitrites, which, when bound to hemoglobin, form methemoglobin, blocking the main function of hemoglobin-to combine and transport oxygen to organs and tissues. Nitrates also prevent the uptake of oxygen by red blood cells, which can cause "cyanosis syndrome" (children suffocate) (Cheng et al., 2012; Yatsyk and Akoev, 1998).

Correlation coefficients between the degree of micronutrient expression and the quantitative mortality rate allow to assess the impact of NO_3^- in groundwater on the health of children (Fig. 3).

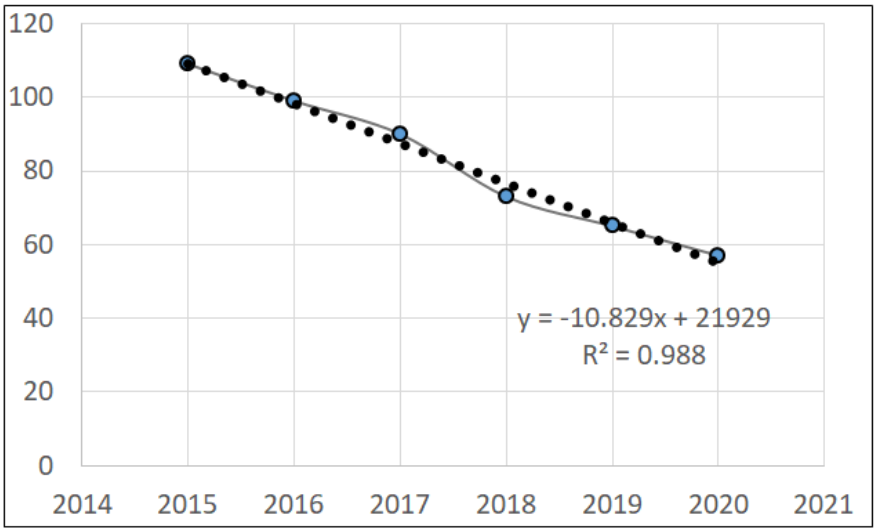

Fig. 3. The number of deaths of children under 1 year.

According to the results of regression analysis, based on which a mathematical model of dynamic changes in mortality of children with logarithmic approximation in the Kiev region. is unfavorable (0.99). In the context of Fastiv and K.-Sviatoshynskyi districts, the correlation coefficient varies considerably, in particular 0.58 and 0.04, respectively.

The burden of HSC per person has been growing over the last two decades, as according to the archives of the Ministry of Health of Ukraine (Melnyk et al., 2017), hematological diseases are increasing every year. Often patients with blood diseases complain of weakness, mild fatigue, dizziness, shortness of breath during exercise, heart failure, loss of appetite, decreased efficiency. These complaints are usually manifestations of various anemias. Malignant blood diseases (hemoblastosis, leukemia) occur in people of all ages, including elderly people and newborns are equally observed in men and women, as evidenced by the high mortality rate among the population of the study areas (Fig. 4).

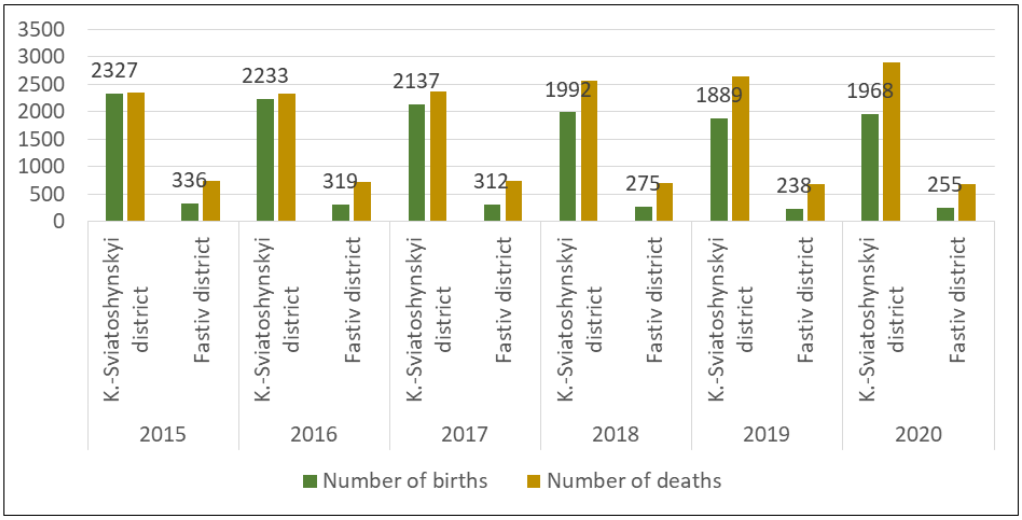

Fig. 4. Natural hands of the population.

Heavy water of high concentration is toxic to the body; chemical reactions in it are slower than ordinary water, and hydrogen bonds with the participation of deuterium are several times stronger than usual. The increased prevalence of peptic ulcer disease in the population consuming water with high mineralization and hardness has been established. In addition, the population of areas that use heavy water, noted the deposition of salts in the urinary tract, changes in water-salt and protein-lipid metabolism.

It is believed that the increased hardness of water disrupts liver function, causes colitis, gastritis, peptic ulcer disease, reduces the acidity of gastric gastric juice, causes diseases of the urinary tract, urolithiasis, gastric diseases. But with long-term consumption of drinking water (more than 1 year) with an excess of certain low-toxic substances (dry residue, total hardness) at the level of 5 and 10 MPC changes in biochemical parameters of liver function in the form of dependence "dose-term-effect". Thus, at high concentrations of heavy water (deuterium) in the body, enzymatic reactions, cell growth, carbohydrate metabolism and nucleic acid synthesis are suppressed. Particularly affected are the systems that are most sensitive to the replacement of H^+ by D^+, in particular the macromolecule biosynthesis apparatus and the respiratory chain (Ignatov and Mosin, 2013; Onishchenko et al., 2002).

It should be noted that due to heavy water, the average daily diet of magnesium can be significantly reduced, and the consumption of soft water leads to an even greater deficiency in the body. Thus, Marier demonstrates the linear dependence of magnesium intake on water hardness and gives the formula for its intake (in milligrams per day) (Marier, 1978):

(0.17 × hardness)+238

This lineal regression allows us to estimate the role of magnesium contained in drinking water. Thus, at zero water hardness, the daily consumption of magnesium reaches 238 mg (due to food), and at a hardness of 8 mg-eq/dm^3-already 306 mg, ie a day

receives an additional 68 mg. In present-day world, magnesium deficiency is one of the most common human deficiencies. The concentration of magnesium in the body decreases under the influence of various factors: living conditions and nutrition, age, exercise, physiological (pregnancy, lactation) and pathological conditions (diseases of the cardiovascular, urinary systems, digestive organs, endocrine glands). Currently, two definitions are used to denote magnesium metabolism disorders: "magnesium deficiency"-a decrease in the total magnesium content in the body and "hypomagnesemia"-a decrease in blood magnesium concentration less than 0.8-1.2 mmol/dm^3. A moderate deficiency of Mg^{2+} in the body is indicated by its level in the blood, which reaches 0.5-0.7 mmol/dm^3, and a relatively life-threatening level-≤0.5 mmol/dm^3 (Mokienko, 2018).

Calcium, as one of the biogenic macronutrients, plays an important role in human life, which is mostly deposited in the bones. Ca^{2+} deficiency in the body can adversely affect the skeletal system, and can also cause cardiovascular disease (Fig. 2) (Kratenko et al., 2004).

Iron is an essential trace element that helps to produce and maintain the body's immunity in most diseases, is involved in hematopoiesis. But its deficiency in the body is usually manifested in iron deficiency anemia, fatigue, pain in the heart, discomfort of the gastrointestinal tract. Excess iron in water (1-5 mg/dm^3) has a negative effect on human skin, causing dryness and itching, and long-term use of such water-develops addiction (Avtsyn et al., 1991).

In general, the list of chemical agents that pollute water is many times longer than air. It would not be an exaggeration to say that almost all the elements and substances used or manufactured by man, one way or another is in the hydrosphere. And dangerous drinking water causes a complex of social and health problems.

Conclusion

During the XX-XXI centuries, a number of regions of Ukraine, in particular Kyiv, face the problem of deteriorating groundwater quality, which, in turn, leads to a significant deterioration in the population health`s.

Analyzing the existing factors influencing water quality on public health, we note that the change in the chemical groundwater composition`s is reflected in the growth of mineralization, macrocomponent content, the appearance of nitrates and is explained primarily by groundwater pollution in alluvial deposits, which are a source of nutrition. Under such conditions, it is logical to assume that the complex man-made factor affects the quality of groundwater, taking into account the infiltration regime of water intake, location above the ground flow of man-made objects, including agricultural objects, unsewered villages, urban housing, etc. Constant use of contaminated drinking water with chemicals causes the development of a pathological condition of the body.

The obtained results allow us to state that in modern social and hygienic conditions a significant part of the population of Kyiv region is at risk of developing many diseases due to the use of poor quality drinking water. The level of risk of deterioration of public health in the studied regions is quite different. But even a small deviation of water quality from the norm is dangerous for humans. Due to the lack or excess of certain trace elements or non-compliance with its stable chemical composition in certain areas from time to time outbreaks of diseases, the cause of which is quite difficult to establish.

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