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THE RISK OF DRINKING WATER WITH EXCESSIVE NITRATE CONTENT BY RESIDENTS OF DIFFERENT AGE CATEGORIES OF THE TERNOPIL REGION

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Abstract

Introduction Human health largely depends on the quality of the water he consumes. The impact of drinking water quality on public health depends on a number of factors. Thus, water pollution with above-normal concentrations of nitrates leads to the occurrence of water-nitrate methemoglobinemia in children, a decrease in the general resistance of the body, which contributes to an increase in the level of general morbidity, in particular, infectious and oncological diseases. It is reported that a positive correlation of the level of cardiovascular morbidity was found in the presence of nitrates.

The aim of the study: to assess the risks of nitrate pollution of water from individual wells on the health of residents of different age groups in certain districts of the Ternopil region.

Material and methods: the research was conducted in 5 districts of Ternopil region. A total of 1,495 samples of drinking water from individual wells were analyzed, the water from which is used to feed all segments of the population, including children and pregnant women.In order to assess the degree of risk of drinking water with excessive nitrate content for the health of the population of different age groups, the indicators of daily intake (ADD) of a chemical substance in the body of consumers and the hazard ratio (HQ) were calculated according to the method of risk assessment from exposure to chemical substances that pollute the environment

Results and discussion: According to the results of laboratory studies, the highest content of nitrates was found in the wells of the Zalishchytsky district - from 57.7 to 153.0 mg/dm3, in other districts the level fluctuated within the following limits: in Pidvolochysk - from 92.4 to 139.0 mg/dm3. Borshchivskyi - from 59.2 to 133.2 mg/dm3, Ternopilskyi - from 73.9 to 98.4 mg/dm3, and Terebovlyanskyi - from 50.5 to 57.8 mg/dm3. The calculated value of the average daily dose (ADD) of the intake of nitrates with drinking water to the body of residents of the above-described regions of the Ternopil region ranges from 2.5 to 7.7 for children; 1.6 - 4.8 - for teenagers (Table 1).; 1.9 - 5.1 for women and 1.8 - 4.9 for men. When assessing the risk to the health of the population, it was found that the hazard ratio at the minimum concentration of nitrates in drinking water determined by us was 1.5 for children, and 1.2 for teenagers. At the maximum concentration of nitrates, the HQ is 4.8 and 3.0, respectively, for children and adolescents. At the minimum concentration of nitrates in drinking water, the hazard ratio for women was 1.0; at the maximum concentration – 3.2. For men, the HQ is 1.0 and 3.0, for minimum and maximum nitrate concentrations

Summary: The risk of negative effects when drinking the same water is greater in children compared to other categories of the population.

Keywords: drinking water; nitrates; hazard risk

Introduction

Providing the population with good-quality drinking water, which is safe from epidemic indicates and harmless in terms of chemical composition, nowadays is one of the most essential problems, because the use of poor-quality drinking water can cause the growth of various non-infectious and infectious diseases in the population [1].

The best type of water supply is considered centralized, which delivers water of guaranteed quality to the population. However, in rural areas, many households use other sources of drinking water, such as streams, wells, and shallow wells [2, 3]. About three-

fourths of the total number of rural residents in Ukraine, or approximately 11 million people, consume water from wells and individual wells, which in the vast majority are in an unsatisfactory sanitary and technical condition [4]. A similar problem is observed in the Ternopil region, where 98.8% of rural settlements are supplied with drinking water from decentralized sources [5].

Traditionally, groundwater is considered safe for drinking. In general, according to the main indicators, they meet the requirements for drinking water. However, the formation of their chemical composition is increasingly occurring not only due to geological structures but also due to the arrival of soluble compounds that get here with rainwater and meltwater from the soil surface. According to monitoring data, in recent years, the concentration of nitrates has increased in both surface and underground waters of the Ternopil region, which enter here from fields when an excessive amount of mineral fertilizers are applied, from livestock and poultry farms, cesspools, and yard latrines, etc [6]. The important problem is that these salts of nitric acid can not be detected without laboratory tests, because they do not affect the smell, taste or transparency of water even at a high concentration. Boiling, settling, or using household filters cannot reduce their content in drinking water.

Nitrates have a particular risk to public health, causing various diseases. One of the most dangerous is water-nitrate methemoglobinemia in children, which leads to oxygen starvation of the tissues and organs of the child's body and can cause death. In the world, there are many cases of poisoned babies who were fed with mixtures prepared from vegetables and fruits contaminated with nitrates, or on water with a high nitrate content. Elderly people, patients with anemia, people with respiratory system diseases, and the cardiovascular system diseases are also sensitive to nitrates [7, 8]. In addition to children, nitrate intoxication is also dangerous for pregnant women. It affects the development of embryos, and long-term exposure of men to water with nitrates negatively affects the function of the testicles, i.e. can be one of the causes of infertility. Indisputable facts have been obtained about the immunosuppressive effect of nitrates, which is manifested by a significant decrease in the body's resistance to the action of carcinogenic and mutagenic agents, which can lead to the development of various diseases and a reduction in life expectancy. It has been established that nitrates and nitrites have carcinogenic properties, which with prolonged exposure to the stomach epithelium can initiate the formation of malignant tumors [9, 10].

Since in recent years nitrates have been detected in the wells of rural residents of the Ternopil region in exceedingly high amounts, the purpose of this work was to calculate the

risk of adverse effects on the health of the population of various ages due to the use of this drinking water in order to further develop priority measures to minimize it.

Material and methods

The research materials are the results of monitoring compliance with standards of drinking water quality indicators from decentralized sources according to sanitary and chemical indicators (namely, nitrates), conducted in the laboratory of the Ternopil Regional Center for Disease Control and Prevention of the Ministry of Health of Ukraine in 2019-2021. 1495 samples of drinking water from decentralized sources of water supply in various districts of Ternopil region, water from which is used for feeding the population, including children and pregnant women. Bibliographic, analytical, hygienic and statistical research methods were used.

In order to obtain quantitative characteristics of the potential and real danger to the health of the population of the Ternopil region from the use of drinking water contaminated with nitrates, a risk assessment methodology was chosen [11]. As indicators of the toxic effect of nitrates on the human body as a result of constant consumption of groundwater without purification, the average daily dose of the chemical substance (ADD), the threshold (reference) dose (RfD) and the hazard ratio (HQ) were calculated.

ADD intake of a chemical substance during a person's life together with drinking water is calculated using formula 1.

$$\mathrm{ADD} = \frac{\mathrm{C\ x\ IR\ x\ ED\ x\ EF}}{\mathrm{BW\ x\ AT\ x\ DPY}} \qquad (1)$$

where: ADD – average daily dose of a chemical substance during life, mg/kg×day;

C – substance concentration in drinking water, mg/dm^3;

IR – amount of water consumption (men – 2.4 dm^3/day; women – 2.3 dm^3/day, teenagers – 1.7 dm^3/day, children – 1 dm^3/day)

ED – duration of exposure (adults – 30 years; children and adolescents – 6 years)

EF – exposure frequency, 350 days/year;

BW – human body weight (men – 75 kg; women – 69kg; teenagers – 54 kg; children – 20 kg)

AT – exposure averaging period, adults – 30 years; children and teenagers - 6 years old

DPY is the number of days in one year, 365 days/year.

The risk of the possible development of non-carcinogenic effects was assessed using hazard ratios. The hazard ratio (HQ) is the ratio of the average daily dose of a chemical substance to its safe (reference) exposure level. It is calculated according to formula 2:

$$HQ = \frac{ADD}{RfD} \quad (2)$$

where: ADD – average daily dose of a chemical substance during life, mg/kg×day;

RfD is the threshold (reference) dose, which is 1.6 mg/kg×day.

Recommended values of reference doses and concentrations with indicating critical organs and systems are presented in Appendix 2 [11].

Results and discussion

According to the results of laboratory studies of the Ternopil Regional Center for Disease Control and Prevention of the Ministry of Health of Ukraine, it was established that in the Ternopil Region out of 17 districts, excess nitrate content was determined in 5 districts. Most often, the nitrate content exceeded the maximum permissible concentration, which according to the "Hygienic requirements for drinking water intended for human consumption" [12] is equal to 50 mg/dm^3 in the southern and southeastern districts of the region, which are located on the Western Podilsk Plato within the Ternopil structurally - stratified plain in the basin of the Dniester River or its tributaries such as the Seret and Zbruch rivers.

According to data for 2019, the highest percentage of water inconsistency in terms of nitrate content was found in Zalishchytskyi and Borshchyvskyi districts - 64.0 and 62.2%, respectively. In the Pidvolochysk district, among the studied wells, 12.5% of the nitrate content exceeded the maximum permissible concentration (MPC), 9.0% in the Ternopilsky district, and 6.0% in the Terebovlyansky district. In 2020, the largest number of samples of drinking water from wells did not meet the normative indicators in the territory of the Pidvolochy district - up to 66.6%. A high percentage of non-conformity (60%) of water in terms of nitrate content was preserved in Borshchiv and Zalishchytskyi districts. But it appeared in 28.5% of the surveyed underground sources of the Husyatinsky District. In 2021, the highest percentage of water inconsistency in terms of nitrate content was observed in the surveyed underground sources of Pidvolochyskyi (70.0%) and Zalishchytskyi (68.8%) districts. Their number increased in Terebovlyanskyi and Ternopilskyi districts (up to 22.9 and 13.0% of samples, respectively).

Thus, in just two years, in the Pidvolochyskyi district, the number of wells with excessive nitrate content increased by 5.6 times (from 12.5% to 70%), in Terebovlyanskyi – by 3.8 times (from 6.0% to 22, 9%), Ternopil - by 1.4 times (from 9.0% to 13.0%). In the

Zalishchytskyi district, consistently high indicators are observed, which range from 64 to 68.8%. However, in Borshchivskyi district, a tendency to decrease the number of underground sources with a high content of nitrates in water is noted from 62.2% to 28.6%.

According to the results of laboratory studies, the content of nitrates in wells in Ternopil region, the water from which is used to feed children and pregnant women, varies within the following limits: in Zalishchytskyi district – from 57.7 to 153.0 mg/dm3, in Borshchivskyi district – from 59.2 to 133.2 mg/dm3, in Pidvolochyskyi district – from 92.7 to 139.0 mg/dm3, in Ternopilskyi district – from 73.9 to 98.4 mg/dm3 and in Terebovlyanskyi district – from 50.5 to 57.8 mg/ dm^3 (Figure 1).

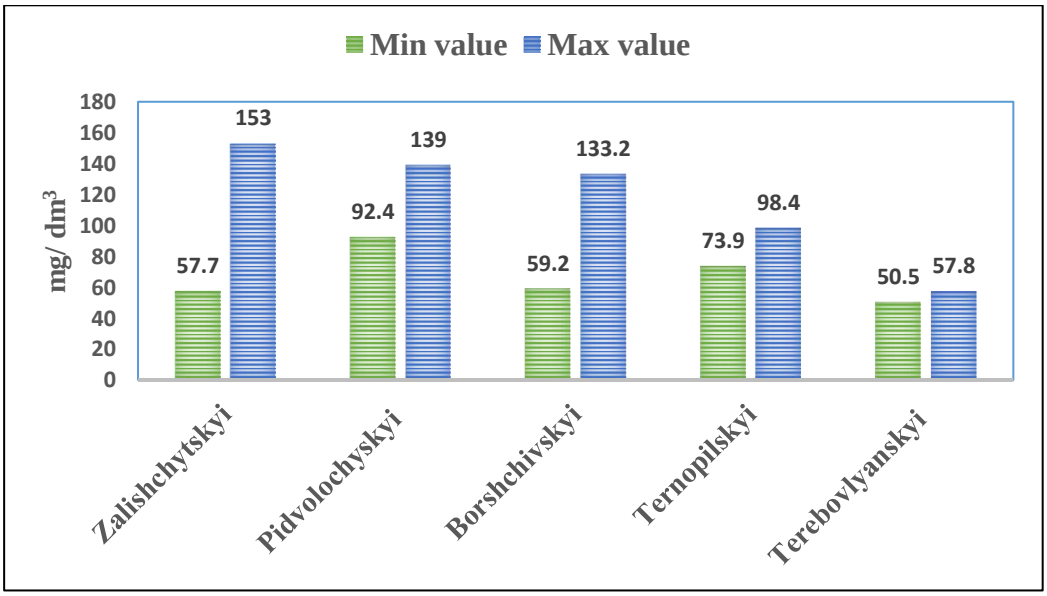

Figure 1. Nitrate content in drinking water of individual wells in certain districts of Ternopil region

It can be assumed that the reasons for the presence of nitrates in wells and sources are irregular use of excessive amounts of organic and inorganic fertilizers by villagers, unregulated effluents from livestock farms and local fecal pollution. It is important to note that the owners of the wells do not comply with the requirements of sanitary legislation in their construction and maintenance, which leads to the contamination of drinking water and makes it unfit for human consumption. Another important factor is that the amount of underground water has decreased in recent years, especially in shallow mine wells, so the concentration of substances diluted in it has increased, especially nitrates [13].

After conducting an analysis of the quality of water in underground sources, we decided to calculate the value of the average daily dose (ADD) of the intake of nitrates with

drinking water to the body of residents of the above-described districts of the Ternopil region. Its indicator varies between 2.5-7.7 mg/kg per day for children and 1.6-4.8 for teenagers, 1.9-5.1 mg/kg per day for women and 1.8 -4.9 – for men (table 1). The largest ADD was noted in the residents of Zalishchytskyi district, the smallest - in Terebovlyanskyi district. In all studied categories of the population, the calculated average daily dose of nitrates in the human body exceeds the reference.

Table 1

Average daily intake of nitrates with drinking water for the population of different ages in the Ternopil region, mg/kg per day

Districts	Average daily intake of nitrates with drinking water, mg/kg per day							
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	Children		Teenagers		Women		Men	
Zalishchytskyi	2,8	7,7	1,8	4,8	1,9	5,1	1,8	4,9
Pidvolochyskyi	4,6	6,7	2,9	4,4	3,0	4,6	2,9	4,4
Borshchivskyi	3,0	6,6	1,9	4,2	2,0	4,4	1,9	4,3
Ternopilskyi	3,7	4,9	2,3	3,0	2,4	3,3	2,4	3,1
Terebovlyanskyi	2,5	2,9	1,6	1,8	1,7	1,9	1,6	1,8

The risk of the possible development of non-carcinogenic effects in residents of the Ternopil region was assessed according to the indicators of the HQ hazard coefficients. Table 2 shows the results of calculations. It was found that the HQ at the minimum concentration of nitrates in drinking water was 1.5 in children and 1.2 in adolescents. At the maximum nitrate concentration, HQ was 4.8 and 3.0, respectively (Table 2).

At the minimum nitrate concentration in drinking water, the HQ for women was 1.0; at the maximum concentration – 3.2. For men, the HQ is 1.0 and 3.0, for minimum and maximum nitrate concentrations.

According to the methodology [11], the value of the risk of non-carcinogenic effects for humans as a result of constant consumption of drinking water with increased nitrate content is classified as follows: up to 0.1 - very low risk; 0.1-1 – low risk; 1-5 – medium risk; 5-10 is high risk and over 10 is critical risk. The risk assessment for public health showed that in all categories of the population, the value of the calculated risk ranges from 1.0 to 4.8,

which indicates the existence of an average risk of harmful negative effects from the consumption of drinking water from local underground sources of water supply. Moreover, the greatest risk exists for children.

Table 2

The coefficient of danger for the population of different ages in the Ternopil region when drinking water with different concentrations of nitrate

Districts	The coefficient of danger at different concentrations of nitrates in drinking water							
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	Children		Teenagers		Women		Men	
Zalishchytskyi	1,8	4,8	1,1	3,0	1,2	3,2	1,1	3,0
Pidvolochyskyi	2,9	4,2	1,8	2,7	1,9	2,9	1,8	2,7
Borshchivskyi	1,9	4,1	1,2	2,6	1,3	2,8	1,2	2,7
Ternopilskyi	2,3	3,0	1,4	1,9	1,5	2,0	1,5	1,9
Terebovlyanskyi	1,5	1,8	1,0	1,1	1,0	1,2	1,0	1,1

Conclusions:

1. The highest concentration of nitrates in drinking water is observed in Zalishchytskyi district with average content 153.0 mg/dm^3, which exceeds the hygienic standard by 3.0 times, and in Borshchiv district, with average content 133.2.0 mg/dm^3, which exceeds 2.6 times the hygienic standard.

2. The average daily dose of nitrates to the human body in all studied areas exceeds the reference, the highest rates are observed in children and women.

3. The value of the calculated risk for the entire population that consumed water from the studied wells ranges from 1.0 to 4.8. These changes are characteristic of the average level of risk of harmful negative effects for all segments of the population.

4. Children are the most sensitive contingent of the population to adverse environmental factors, including nitrate content in drinking water. The above calculations showed that both ADD and HQ are greater for children than for the adult population.

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