quality of working life of university teachers from different areas of knowledge. Cien Saude Colet. 2019;24:4111-23. doi: https://doi.org/10.1590/1413-812320182411.28712017

14. Singh OP, Singh SK. Quality of Work Life of Teachers Working in Higher Educational Institutions: A Strategic Approach towards Teacher's Excellence. Int J Adv Res Comput Sci Manag Stud. 2015;3:180-6.

15. Sjøgaard JR. Christensen JB, Justesen JB, et al. Exercise is more than medicine: the working age population's well-being and productivity. J of Sport and Health Science. 2016;5(2):159-65. doi: https://doi.org/10.1016/j.jshs.2016.04.004

Стаття надійшла до редакції
17.05.2021

UDC 311.16:[616-036.88:543.3](477.42) https://doi.org/10.26641/2307-0404.2023.1.276204

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# ASSESSMENT OF CORRELATION RELATIONSHIPS BETWEEN THE LEVEL OF MORTALITY OF THE POPULATION OF ZHYTOMYR REGION OF UKRAINE FROM NON-INFECTIOUS DISEASES AND SANITARY-CHEMICAL INDICATORS OF SAFETY AND QUALITY OF DRINKING WATER

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***Цитування: Медичні перспективи. 2023. Т. 28, № 1. С. 161-167***
***Cited: Medicni perspektivi. 2023;28(1):161-167***

**Key words:** *mortality, non-communicable diseases, sanitary-chemical indicators of safety and quality of drinking water, correlation relationships, population of Zhytomyr region of Ukraine*
**Ключові слова:** *смертність, неінфекційні захворювання, санітарно-хімічні показники безпечності та якості питної води, кореляційні зв'язки, населення Житомирської області України*

**Abstract. Assessment of correlation relationships between the level of mortality of the population of Zhytomyr region of Ukraine from non-infectious diseases and sanitary-chemical indicators of safety and quality of drinking water. Zablotska O.S., Kyrychuk I.M., Shcherba N.S., Nikolaieva I.M.** *The purpose of the publication was to assess the strength and direction of correlation relationships between mortality rates from non-communicable diseases of the population of Zhytomyr region of Ukraine and sanitary-chemical indicators of safety and quality of drinking water. The need for this study was determined by the necessity to adjust existing and develop new strategic approaches to the prevention of non-communicable diseases that depend on the level of chemical contamination of drinking water. The study was conducted in 2016-2020. Standardized indicators of mortality from non-communicable diseases (per 100,000 population) were analyzed. 25375 water samples were studied, among them 8339 belonged to centralized and 17036 – to decentralized water supply. The strength and direction of correlation relationships between population mortality rates from non-communicable diseases and the average values of sanitary-chemical indicators of drinking water were determined by Pearson's linear correlation coefficients and the Chaddock scale. The statistical significance of the correlation coefficients was determined by Student's t-test. In the process of research work such methods as: bibliographic, medical and sociological, retrospective, epidemiological, statistical, system analysis and generalization were used. Statistically significant ($p<0.05$) strong direct correlations were found between mortality rates of the urban population of Zhytomyr region from diseases of the circulatory system (I00-I99) (including myocardial infarction) (I21-I22), coronary heart disease (I20-I25), of digestive organs (K00-K93) and average total iron and total hardness values; between nervous system diseases (G00-G99) and average values of manganese in drinking water of centralized water supply, as well as between mortality rates of rural population from diseases of the circulatory system (I00-I99) and average values of total hardness, total iron and nitrates in drinking water of decentralized water supply. The urgent need to develop new strategic approaches to improve the quality of drinking water in the region as one of the factors in the prevention of non-communicable diseases has been proved.*

**Реферат. Оцінка кореляційних зв'язків рівня смертності населення Житомирської області України від неінфекційних захворювань із санітарно-хімічними показниками безпечності та якості питної води. Заблоцька О.С., Киричук І.М., Щерба Н.С., Ніколаєва І.М.** *Мета публікації полягала в оцінці сили й напряму кореляційних зв'язків між рівнями смертності від неінфекційних захворювань населення Житомирської області України та санітарно-хімічними показниками безпечності та якості питної води. Потреба в цьому дослідженні визначалася необхідністю корегування існуючих і розроблення нових стратегічних підходів до профілактики неінфекційних захворювань, залежних від рівня хімічного забруднення питної води. Дослідження проводилося протягом 2016-2020 рр. Проаналізовано стандартизовані показники випадків смертності населення від неінфекційних хвороб (на 100 тис. населення). Вивчено хімічний склад 25375 проб води, з них 8339 – централізованого і 17036 – нецентралізованого водопостачання. Сила й напрям кореляційних зв'язків рівнів смертності населення від неінфекційних хвороб із середніми значеннями санітарно-хімічних показників у питній воді встановлювалися за коефіцієнтами лінійної кореляції Пірсона та шкалою Чеддока. Статистична значущість коефіцієнтів кореляції визначалася за t-критерієм Стьюдента. У процесі дослідницької роботи використано методи: бібліографічний, медико-соціологічний, ретроспективний, епідеміологічний, статистичний, системного аналізу та узагальнення. Установлено статистично достовірні ($p<0,05$) сильні прямі кореляційні зв'язки рівнів смертності міського населення Житомирського регіону від хвороб системи кровообігу (I00-I99) (у т.ч. – інфаркту міокарда (I21-I22), ішемічної хвороби серця (I20-I25)) та органів травлення (K00-K93) із середніми значеннями заліза загального і загальної жорсткості; хвороб нервової системи (G00-G99) – із середніми значеннями марганцю в питній воді централізованого водопостачання, а також між рівнями смертності сільського населення від хвороб системи кровообігу (I00-I99) із середніми значеннями загальної жорсткості, заліза загального та нітратів у питній воді нецентралізованого водопостачання. Доведено нагальну потребу в розробці нових стратегічних підходів до покращення якості питної води в регіоні як одного з чинників профілактики неінфекційних хвороб населення.*

According to the UN Environment Assembly (Nairobi, 2017) and the Lancet Commission on pollution and health, chemical contamination of drinking water is one of the main causes of non-communicable diseases (NCDs) development in population [4, 6, 11]. The share of deaths from NCDs caused by long-term consumption of low-quality drinking water is 22% in the world [11]. In order to develop preventive measures for these diseases, numerous attempts have been made to establish correlation relationships between individual sanitary-chemical indicators (SCI) of drinking water and NCDs of the population of different regions of the planet [4]. In most cases, the nature of such relationships is not fully disclosed [11], due to the long latent course of NCDs. The need to study the state of chemical pollution of drinking water at the level of countries and their administrative territories has been identified as a prevention factor of NCDs [6].

The purpose of the publication was to assess the strength and direction in the correlation relationships between the level of mortality from non-communicable diseases of the population of the united territorial communities (UTC) of Zhytomyr region of Ukraine and SCI of safety and quality of drinking water. The need for this study was determined by the necessity to adjust existing and develop new strategic approaches to the prevention of NCDs, that depend on the level of chemical pollution of drinking water in the region.

**MATERIALS AND METHODS OF RESEARCH**

The study was conducted in 2016-2020 in nine UTC (total area – 9341.2 km$^2$, population in 2020 – 262203, each year the population decreased by 1-2%). According to the data of inter-district departments of Zhytomyr Regional Laboratory Center of the Ministry of Health of Ukraine, the chemical composition of 25,375 water samples was studied (of which 8,339 belonged to centralized and 17,036 – to decentralized water supply). Using the sanitary-chemical indicators (SCI) the share of deviations (SOD) from SCI of Ukraine [2] was calculated as well as the average absolute values of the SCI for which deviations were observed, according to the seasons of each of the five years of the study period (n=20) (AV) and standard deviations (SD) from them, as well as perennial AV of SCI (PAV) and SD from them.

According to the statistical directories of the Department of Health of Zhytomyr Regional State Administration, standardized mortality rates (per 100,000 population) from NCDs were studied. NCD names were suggested according to the International Classification of Diseases, 10th revision (ICD-10). The strength and direction of correlation relationships were determined by Pearson's linear correlation coefficients (r) and the Chaddock scale. The statistical significance of r was determined by Student's t-test [1].

In the process of research the following methods were used: bibliographic, medical-sociological, retrospective, epidemiological, statistical, system analysis and generalization [1]. Statistical analysis was performed by means of Microsoft Excel 2019 software (license number H2R4K-G3WDH-WYJQ9-JDX6H-HCKDZ). The research is in accordance with the principles of bioethics, enshrined in the Helsinki Declaration.

**RESULTS AND DISCUSSION**

The results of the analysis of sanitary-chemical researches have shown that during the last years there is a steady tendency to deterioration of the quality of the chemical composition of drinking water in Zhytomyr region. There is a heterogeneity in the distribution of SOD from the norm for SCI safety and quality of drinking water in the studied UTC. For instance, the SOD in drinking water of centralized water supply increased significantly in 2020, compared to 2016, in Narodytska (from 46.6% to 91.5%), Yemilchynska (from 38.5% to 84.2%) and Ovrutska (from 24.9% to 71.7%) UTC, as well as in the region as a whole (from 21.8% to 39.6%). Improvement of drinking water quality in terms of sanitary-chemical indicators was recorded only in Baranivska and Radomyshlska UTC, where SOD decreased from 54.7% to 30.0% and from 80.7% to 43.6%, respectively.

In the drinking water of decentralized water supply, SOD by SCI increased significantly in Narodytska (from 11.1% to 56.3%) and Ovrutska (from 33.4% to 50.5%) and decreased only in Baranivska UTC (from 58, 5% to 30.4%).

In the studied samples of drinking water of centralized water supply the deviations from the norm by SCI were: total iron, total hardness and manganese, and in drinking water of decentralized water supply they were: total iron, total hardness and nitrates. SOD by SCI differed significantly in the drinking water of some UTC.

The analysis of mortality rates of the urban population of the studied UTC showed an increase in 2020 (compared to 2016) of mortality rates from circulatory system diseases (I00-I99) (including myocardial infarction (I21-I22) and coronary heart disease (I20-I25) and digestive system diseases. The significant increase of mortality rates from myocardial infarction (I21-I22) was recorded in Novograd-Volynska UTC (from 9.7 to 16.3 per 100 thousand population), from coronary heart disease (120-125) – in Olevska and Ovrutska UTC (from 363.9 to 622,6 and from 408.9 to 642.2 per 100 thousand population, respectively).

In 2020, compared to 2016, the death rate of the rural population from myocardial infarction (I21-I22), coronary heart disease (I20-I25) and digestive system diseases (K00-K93) increased. A significant increase in mortality rates from myocardial infarction (I21-I22) and coronary heart disease (I20-I25) was observed in Narodytska UTC (from 0.0 in 2016 to 15.3 in 2020 per 100 thousand population, respectively).

The process of finding correlations between the mortality rates of the population of Zhytomyr region from classes and certain nosological forms of NCDs and AV of SCI of the quality and safety of drinking water was guided by the premise that the urban population supplies drinking water of centralized and rural – of non-centralized water supply. The results of calculations of Pearson's linear correlation coefficients (r) between the studied indicators are given in Tables 1, 2.

*Table 1*

**Correlation coefficients (r) (p<0.05) of mortality rates from NCDs of the urban population of the studied UTC of Zhytomyr region of Ukraine and AV of SCI of safety and quality of drinking water of centralized water supply**

| Mortality from NCD | Coefficients of linear correlation (r) with AV of SCI in the studied UTC | | |
|---|---|---|---|
| | total iron | total hardness | manganese |
| C00-D48 | 0.53 (Baranivska) | 0.54 (Baranivska) | – |
| E00-E90 | – | – | – |
| G00-G99 | – | – | 0.55 (Malynska), 0.82 (Pulynska) |
| K00-K93 | 0.76 (Ovrutska) | 0.76 (Ovrutska), 0.48 (Pulynska) | 0,46 (Novograd-Volynska) |
| N00-N99 | – | – | – |
| I00-I99 | 0.79 (Novograd-Volynska) | 0,82 (Ovrutska), 0.79 (Novograd-Volynska) | – |
| I21-I22 | 0.93 (Novograd-Volynska) | 0.94 (Novograd-Volynska) | – |
| I20-I25 | 0.50 (Novograd-Volynska), 0.74 (Olevska), 0.90 (Ovrutska) | 0.49 (Novograd-Volynska), 0.89 (Ovrutska) | – |

Tables 1 and 2 do not include linear correlation coefficients, which indicate weak correlations (r<0.30), which is explained by their statistical insignificance caused by a small sample of our study (n=20) (p>0.05). The lack of such data somewhat limited, but did not significantly affect the conclusions, because to establish the likelihood of existing causal links between two series of studied indicators, to predict the probability of increasing values of one of the series of variables due to their growth in another, to determine the mechanisms for adjusting value indicators of one of the series of variables by changing the values of the other in the linear correlation analysis the value of r≥0,70 is used [1].

*Table 2*

**Correlation coefficients (r) (p<0.05) of mortality rates from NCDs of the rural population of the studied UTCs of Zhytomyr region of Ukraine and AV of SCI of safety and quality of drinking water of decentralized water supply**

| Mortality from NCD | Coefficients of linear correlation (r) with AV of SCI in the studied UTC | | |
|---|---|---|---|
| | total iron | total hardness | nitrates |
| C00-D48 | 0.50 (Radomyshlska) | 0.61 (Radomyshlska) | 0.40 (Radomyshlska) |
| E00-E90 | – | – | 0.57 (Radomyshlska) |
| G00-G99 | – | – | – |
| K00-K93 | 0.70 (Ovrutska) | – | – |
| N00-N99 | – | – | – |
| I00-I99 | 0.60 (Narodytska) 0.72 (Radomyshlska) | 0.47 (Malynska), 0.61 (Narodytska) | 0.81 (Yemilchynska), 0.71 (Radomyshlska) |
| I21-I22 | 0.96 (Narodytska) | 0.95 (Narodytska), 0.45 (Radomyshlska) | 0.92 (Yemilchynska) |
| I20-I25 | 0.67 (Radomyshlska), 0.61 (Ovrutska), 0.86 (Narodytska) | 0.87 (Narodytska) | 0.48 (Yemilchynska), 0.66 (Radomyshlska) |

**Notes:** r≥0.70 – strong correlations; r≥0.30 – <0.70 - correlations of moderate strength; "-" – no statistically significant correlations were found (p>0.05).

Despite the fact that long-term consumption of poor quality drinking water is only one factor in the formation of NCDs and mortality from them in the simultaneous impact of genetic, medical, social, behavioral and other determinants on the health of the population, we can conclude on the basis on our calculations (Tables 1, 2), that there is a high probability of causal relationships between the studied indicators.

The effect of high concentrations of total iron in drinking water on the morbidity and mortality of people from NCDs has been and is the subject of study by many scientists around the world, including Ukraine. The existence of a direct correlation with morbidity and/or mortality from malignant neoplasms (C00-D48) [5], diseases of the nervous (G00-G99), urogenital (N00-N99), circulatory (I00-I99), endocrine system, disorders of eating and metabolic systems (E00-E90) and of digestive organs (K00-K93) has been proved on the example of different countries and their administrative territories [7]. No statistically significant effect of iron on the morbidity and mortality of the Finnish population from myocardial infarction was revealed (121-122) [9].

Our results correlate with previous studies on the presence of a strong direct correlation between the AV of total iron in drinking water of centralized and decentralized water supply and the mortality rates of the studied UTC of Zhytomyr region from digestive organ diseases (K00-K93) (with PAV±SD total iron - 0.811±0.1558 mg/dm$^3$ and more), and also of the circulatory system (I00-I99), including the myocardial infarction (121-122) and the coronary heart disease (120-125) (with PAV±SD of the total iron – 0, 3672±0.0673 mg/dm$^3$ and more).

The existence of a direct correlation between the moderate strength AV of total iron in drinking water and the mortality rates of urban (with total iron PAV±SD of 0.5922±0.1161 mg/dm$^3$) and of rural (with total iron PAV±SD of 0.6683±0.2400 mg/dm$^3$) population from malignant neoplasms (C00-D48) was established.

Comparing the PAV±SD above, we can conclude that the human circulatory system is more sensitive to the negative effects of total iron than other systems.

No correlations have been identified between the AV of total iron in drinking water and the mortality rates from endocrine diseases, eating and metabolic disorders (E00-E90), diseases of nervous (G00-G99) and urogenital systems (N00-N99) in contrast to previous studies.

The data presented in scientific publications on the correlation of total hardness in drinking water and morbidity and mortality rates from diseases of the circulatory system (I00-I99) are ambiguous: both direct [4] and inverse [10] correlation has been found. A strong inverse correlation was found with the levels of morbidity and mortality from myocardial infarction (121-122) and coronary heart disease (120-125) [9, 13] and malignant neoplasms (C00-D48); the direct correlation exists with mortality rates from diseases of the digestive system (K00-K93); both – direct and reverse with diseases of the genitourinary system (N00-N99) [3, 11, 12].

In our study, we found only direct correlations between the AV of total hardness and mortality rates from the diseases of the circulatory system (I00-I99) (with PAV±SD of total hardness in centralized drinking water – 4.9760±0.3222 mmol/dm$^3$ and 11.2350±1.5068 mmol /dm$^3$ in non-centralized water supply), and also of system of digestive organs of the urban population (K00-K93) (with PAV±SD of total hardness in drinking water of the centralized water supply – 7.8397±0.5964 mmol/dm$^3$). No correlations were found between the AV of total hardness in drinking water of decentralized water supply and mortality rates from diseases of the digestive system of the rural population (K00-K93), which is explained by the predominance of the influence of other determinants of health in rural areas, primarily quality nutrition, physical activity, etc.

In contrast to previous studies, a strong direct correlation was found between the AV of total hardness of non-centralized drinking water and the mortality rates of the rural population from malignant neoplasms (C00-D48) (with the PAV±SD of total hardness of 10.4065±2.5564 mmol/dm$^3$) and direct correlation of moderate strength with the mortality rates of the urban population from these diseases (with the PAV±SD of total hardness of 6.0598±0.5590 mmol /dm$^3$).

No correlations were found between mortality rates with the diseases of the genitourinary (N00-N99), nervous (G00-G99) and endocrine systems, eating and metabolic disorders (E00-E90).

It has been established that the human circulatory system is the most sensitive to the negative effects of total hardness in drinking water.

Numerous studies on the effects of manganese in drinking water on public health have shown a strong direct correlation with morbidity and/or mortality from malignancies (C00-D48) [5], endocrine diseases, eating and metabolic disorders. E00-E90) [13], nervous (G00-G99), urogenital (N00-N99), circulatory systems (I00-I99) and digestive organs (K00-K93) [7].

As our calculations show (Table 1), a strong direct correlation between the AV of manganese in drinking water of centralized water supply and urban mortality rates exists only for diseases of the nervous system (G00-G99) (for the PAV±SD of manganese of 0.1796±0.0499 mg/dm$^3$). If the PAV±SD of

manganese in drinking water of centralized water supply is 0.04961±0.0076 mg/dm$^3$ there is a direct correlation of moderate strength between the studied indicators.

In contrast to previous studies by scientists around the world the existence of direct moderate strength correlations between manganese indices in drinking water and urban population mortality from the diseases of the digestive system (K00-K93) (with the PAV±SD of manganese 0.0750±0.0092 mg/dm$^3$) has been proved. No correlations were found between mortality from malignancies (C00-D48), diseases of the endocrine system, eating and metabolic disorders (E00-E90), circulatory (I00-I99) and urogenital system (N00-N99).

The problem of the impact of nitrates on public health is especially relevant for rural areas, where the quality of drinking water is mainly not controlled by well owners. Studies in this area examined not only the correlation between increased nitrate concentrations ($NO^{3-}$) (>50.0 mg/dm$^3$) and NCD mortality rates, but also low and medium concentrations, as the WHO recommended standard was set to prevent pediatric methemoglobinemia without consideration of other negative consequences for public health [14]. There is a strong direct correlation between different concentrations of nitrates in drinking water and the mortality rates of rural population from malignant neoplasms (C00-D48), namely: >10.0 mg/dm$^3$ – cancer of the colon and rectum [14], medium levels of nitrates – with malignant neoplasms of the bladder [8]. Strong direct correlations have been established between high nitrate concentrations and morbidity and mortality rates from genital (N00-N99) [11] and endocrine system diseases, eating and metabolic disorders (E00-E90) – hypothyroidism and type 1 diabetes [14].

No associations have been found between average nitrate concentrations in decentralized drinking water and mortality rates from diseases of the nervous (G00-G99), circulatory (I00-I99) and digestive system (K00-K93) [14].

The results of our studies indicate the presence of direct correlations of moderate strength between the AV of medium concentrations of nitrates in drinking water and mortality rates of the rural population from malignant neoplasms (C00-D48) and diseases of the endocrine system, eating and metabolic disorders (E00-E90) (with PAV±SD 34.4195±10.4276 mg/dm$^3$). In contrast to previous studies, strong direct correlations have been found between the mortality rates of the rural population from circulatory system diseases (I00-I99), including myocardial infarction (121-122) and coronary heart disease (120-125) and AV of medium concentrations of nitrates in drinking water (with PAV±SD 34.4195±10.4276 mg/dm$^3$ and more).

No correlations were found between the AV of medium concentrations of nitrates in decentralized drinking water and the mortality rates of the rural population from diseases of the nervous (G00-G99), digestive (K00-K93) and urogenital systems (N00-N99).

As it can be seen from Tables 1 and 2, the most problematic UTC in Zhytomyr region, which show strong direct correlations between mortality rates from NCD and the AV of SCI of the quality and safety of drinking water are Novograd-Volynska, Ovrutska (centralized water supply), Narodytska and Radomyshlska (decentralized water supply). According to our calculations, despite the low intensity of the influence of chemical components in drinking water on public health, further deterioration of its quality in these regions will lead to a directly proportional increase in mortality rates from NCDs. To prevent such consequences, it is necessary to strengthen control over the chemical composition of drinking water in the region and develop additional measures to purify it from excessive amounts of total iron, total hardness, manganese and nitrates.

It is worth using the experience of other countries and to publish on public websites of departments of ecology and natural resources of various administrative territories of Ukraine, including – Zhytomyr region, information on levels of SCI in drinking water, possible health risks due to consumption of drinking water with significant SOD from the defined standards, methods and frequency of testing the quality of drinking water of decentralized water supply, its purification at home, the list of organizations that provide advice on this issue.

**CONCLUSION**

1. During 2016-2020, in the drinking water of the centralized water supply of Zhytomyr region of Ukraine there was recorded a significant share of sanitary and chemical indicator deviations of total iron, total hardness and manganese, and decentralized water supply – of total iron, total hardness and nitrates. The distribution of average values of the data of sanitary-chemical indicators in the drinking water of the studied united territorial communities is inhomogeneous.
2. Statistics shows that mortality rate from non-communicable diseases – of circulatory system (I00-I99) (including – myocardial infarction (I21-I22) and coronary heart disease (I20-I25) and digestive organs (K00-K93) among the urban population, as well as from myocardial infarction (I21-I22), coronary heart disease (I20-I25) and digestive organs (K00-K93) among the rural population increased during the indicated period in Zhytomyr region.
3. Strong direct correlations have been found between average values of total iron and total hardness in drinking water of centralized water

supply and mortality rates of urban population from diseases of the circulatory system (I00-I99) and digestive organs (K00-K93); between manganese and diseases of the nervous system (G00-G99), as well as between the average values of total iron, total hardness and nitrates in drinking water of decentralized water supply and mortality rates of the rural population from diseases of the circulatory system (I00-I99) (including – myocardial infarction (I21-I22) and coronary heart disease (I20-I25)).

4. An increase in the mortality rate of the population of the united territorial communities of Zhytomyr region of Ukraine from non-communicable diseases can be predicted under the condition of further consumption of low-quality drinking water. Therefore, there is an urgent need to develop new strategic approaches to improve the quality and safety of drinking water as one of the factors in the prevention of non-communicable diseases.

**Contributors:**

Zablotska O.S. – conceptualization, methodology, verification, formal analysis, research, data curation, writing – the initial project, editing, visualization, management, project administration;

Kyrychuk I.M. – formal analysis, research, reviewing;

Scherba N.S. – formal analysis, research, writing – initial design, editing, visualization;

Nikolaieva I.M. – verification, the formal analysis, research, editing.

**Funding.** This research received no external funding.

**Conflict of interests.** The authors declare no conflict of interest.

## REFERENCES

1. Antomonov MYu. [Mathematical processing and analysis of medical and biological data]. 2nd ed. Kyiv: MYCz "Medynform"; 2018. 579 p. Russian.

2. [State sanitary norms and rules. Hygienic requirements to drinking water intended for human consumption. (SSanRaN 2.2.4-171-10). The order of the Ministry of Health of Ukraine N 400 from 12 May 2010]. (2010). Ukrainian. Available from: http://zakon4.rada.gov.ua/laws/show/z0452-10

3. Lypovetska OB. [The influence of the mineral composition of drinking water on diseases of the digestive organs of the adult population (on the example of the city of Kherson)]. Hihiiena naselenykh mists. 2015;65:73-9. Ukrainian.

4. Prokopov VO. [Drinking water of Ukraine: medical, ecological, sanitary and hygienic aspects]. Kyiv: A-USPH "Medicine"; 2016. 400 p. Ukrainian.

5. Fallahzadeh RA, Ghaneian MT, Miri M, Dashti MM. Spatial analysis and health risk assessment of heavy metals concentration in drinking water resources. Environ Sci Pollut Res Int. 2017;24(32):24790-802. doi: https://doi.org/10.1007/s11356-017-0102-3

6. Fuller R, Rahona E, Fisher S, Caravanos J, Webb D, Kass D, et al. Pollution and non-communicable disease: time to end the neglect. The Lancet Glob Health. 2018 Mar;2(3):96-8. doi: https://doi.org/10.1016/S2542-5196(18)30020-2

7. Ghosh GC, Khan MJ, Chakraborty TK, Zaman S, Kabir AE, Tanaka H. Human health risk assessment of elevated and variable iron and manganese intake with arsenic-safe groundwater in Jashore, Bangladesh. Sci Rep. 2020;10:1-9. doi: https://doi.org/10.1038/s41598-020-62187-5

8. Jones RR, Weyer PJ, DellaValle CT, Inoue-Choi M, Anderson KE, Cantor KP, et al. Nitrate from drinking water and diet and bladder cancer among postmenopausal women in Iowa. Environ. Health Perspect. 2016;124:1751-8. doi: https://doi.org/10.1289/EHP191

9. Kousa A, Moltchanova E, Viik-Kajander M, Rytkönen M, Tuomilehto J, Tarvainen T, et al. Geochemistry of ground water and the incidence of acute myocardial infarction in Finland. J Epidemiol Community Health. 2014;58(2):136-9. doi: https://doi.org/10.1136/jech.58.2.136

10. Kozisek F. Regulations for calcium, magnesium or hardness in drinking water in the European Union member states. Regul Toxicol Pharm. [Internet]. 2020 April [cited 2022 Dec 02];112:104589. doi: https://doi.org/10.1016/j.yrtph.2020.104589

11. Landrigan PJ, Fuller R, Acosta NJ, et al. The Lancet Commission on pollution and health. Lancet Comm. 2018;391:462-512. doi: https://doi.org/10.1016/S0140-6736(17)32345-0

12. Sarfraz M, Sultana N, Tariq MI. Hazardous pollutants in potable groundwater sources of public schools, Southern Punjab (Pakistan). Rev Int Contam. 2019;35(4):797-805. doi: https://doi.org/10.20937/RICA.2019.35.04.02

13. Shlezinger M, Amitai Y, Goldenberg I, Shechter M. Desalinated seawater supply and all-cause mortality in hospitalized acute myocardial infarction patients from the Acute Coronary Syndrome Israeli Survey 2002-2013. Int J Card. 2016 Oct;220(1):544-50. doi: https://doi.org/10.1016/j.ijcard.2016.06.241

14. Ward MH, Jones RR, Brender JD, Kok ThMDe, Weyer PJ, Nolan BT, et al. Drinking Water Nitrate and Human Health: An Updated Review. Int J Environ Res Public Health. [Internet]. 2018 [cited 2022 Dec 06];15(7):1557. doi: https://doi.org/10.3390/ijerph15071557

Стаття надійшла до редакції
21.10.2021