ORIGINAL ARTICLE

CONTENTS

The role of mine water pollution in increasing the risk of malignant neoplasms among the population of industrially affected region of Ukraine

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ABSTRACT

Aim: To assess the potential impact of mine water contamination on the increased risk of malignant neoplasms among the population of an industrially affected region of Ukraine (Kryvyi Rih Iron Ore Basin).

Materials and Methods: Hygienic, epidemiological and statistical methods of research were used in the study. The study of mine water was conducted using samples obtained from 63 points representing the main mining horizons of the Kryvyi Rih Iron Ore Basin (Ukraine), using the following indicators: dissolved oxygen, biochemical oxygen demand over 5 days (BOD_5), hydrogen index (pH), suspended solids, chemical oxygen demand (COD), dry residue, chlorides, sulfates, ammonium nitrogen, nitrites, nitrates, phosphates, oil products, total iron, and phenols.

Results: Laboratory analysis of mine water revealed that the concentrations of several substances exceeded permissible levels. The integral pollution coefficients suggested the water to be extremely polluted, and the ecological state of the environment as critical. The risk of malignant neoplasms in the Kryvyi Rih industrial region was 25,054 (95% CI 25,010–25,098). Teenagers aged 15–17 had the highest risk of developing malignant neoplasms (OR 16,310 [95% CI 5,927–44,888]). Children under the age of 14 ranked second (OR 5,528 [95% CI 3,423–8,925]). Adults (≥18 years old) had a lower risk of malignant neoplasms (OR 2,461 [95% CI 2,309–2,622]). Children and adolescents were more affected than adults, i.e. the etiologic fraction of mine water pollution in the development of malignant neoplasms was 81,9% and 94,3%, respectively (vs. 59,6% in adults).

Conclusions: Considering the extremely polluted state of mine waters in the industrially affected region of Ukraine, and assessing the related malignant neoplasm risks in the context of public health, the development of innovative preventive strategies and methodologies is required, taking into account all relevant determinants, including environmental factors.

KEY WORDS: water pollution, malignant neoplasm, industrial regions

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INTRODUCTION

Pollution of natural water sources is one of the main factors impacting the environment and public health [1, 2].

The multifactorial and multidirectional nature of the environment's impact on humans determines the procedural aspects of complex assessment of its quality and requires the creation of new approaches. Currently, the issues of quantitative assessment of the intensity of environmental factors' impact on public health are not sufficiently studied [3].

Industrial regions are characterized by a high concentration of enterprises, including mining and processing industries, which generate varying amounts of wastewater as a result of their activities. The composition and quality of this wastewater primarily depend on the raw materials and the technological processes employed, while the volume often exceeds several times the amount of water actually used by the industrial enterprises themselves. The wastewater collected is subjected to varying degrees of treatment before being discharged into water bodies or reused for mining operations or other industrial sectors. The requirements for wastewater quality, both upon discharge into water bodies and during subsequent use, necessitate the extensive application of diverse treatment methods and technologies [1, 4].

Malignant neoplasms, together with cardiovascular diseases, are key determinants of a nation's health status, as cancer ranks among the leading causes of mortality and disability. It accounts for approximately 12% of deaths (up to 15% according to some authors [5]) and 26% of disability cases, particularly affecting individuals of reproductive and working age. Among the working-age population, cancer-related mortality accounts for 14% of deaths in men and 29% in women [6–8].

AIM

To assess the potential impact of mine water contamination on the increased risk of malignant neoplasms among the population of an industrially affected region of Ukraine (Kryvyi Rih Iron Ore Basin).

MATERIALS AND METHODS

The hygienic, epidemiological, and statistical methods of research were used to achieve the study aim. The study of mine water was conducted using samples obtained from 63 points representing the main mining horizons of the Kryvyi Rih Iron Ore Basin (Ukraine), using the following indicators: dissolved oxygen, biochemical oxygen demand over 5 days (BOD_5), hydrogen index (pH), suspended solids, chemical oxygen demand (COD), dry residue, chlorides, sulfates, ammonium nitrogen, nitrites, nitrates, phosphates, oil products, total iron, and phenols.

The laboratory analyses were carried out at the Kryvyi Rih District Laboratory of Research and at the University's scientific laboratory (Kryvyi Rih, Ukraine). The obtained results were compared with hygienic standards established for water bodies used for domestic and other public needs in Ukraine [9].

Certain integral coefficients were estimated in accordance with approved methodologies [9–11], namely the Water Pollution Index (WPI), the Conditional Complexity Coefficient (CCC), and the Complex Pollution Index (CPI).

The WPI (arbitrary units [a.u.]) was calculated based on the abovementioned 15 indicators according to the following formula:

$$WPI = \frac{1}{15}\sum_{i=1}^{15}\frac{C_i}{MAC_i}$$

where C_i is the arithmetic mean value of the i-th water quality parameter, and MAC_i MAC_i is its corresponding maximum allowable concentration (MAC).

The WPI was interpreted according to the following classes: [≤ 0,30] – class I (very clear); [0,31 – 1,00] – class II (clear); [1,01 – 2,50] – class III (moderately polluted); [2,51 – 4,00] – class IV (polluted); [4,01 – 6,00] – class V (heavily polluted); [6,01 – 10,0] – class VI (severely polluted); and [>10,0] – class VII (extremely polluted).

The CCC (%) was calculated according to the following formula:

$$CCC = \frac{m'}{m} \times 100\%$$

where m' m' is the number of parameters with concentrations exceeding the MAC, and m is the total number of regulated parameters included in the study. When CCC <10%, an analysis of specific pollutants is carried out individually.

The CPI (a.u.) was calculated according to the following formula:

$$CPI = \sum_{i=1}^{n}\frac{C_i}{MAC_i}$$

where C_1, C_2, … , C_n are the concentration values of various pollutants in mine water (mg/dm^3), and MAC_1, MAC_2, … , MAC_n are the corresponding MACs for these pollutants. The degree of groundwater pollution and the ecological condition of the natural environment were assessed based on the Table 1.

The level of contamination (K_i) (a.u.) was calculated according to the following formula:

$$K_i = \frac{C_i}{MAC_i}$$

where C_i is the measured concentration of the i-th pollutant, and MAC_i is its MAC.

The level of pollution of water bodies was determined according to the following K_i rating: [0 ÷ 2] – low; [2 ÷ 10] – moderate; [10 ÷ 50] – high; [50 ÷ 100] – very high.

Our previous studies have revealed an association between the concentration of chemical substances in mine waters and the incidence of malignant neoplasms among the population of the Kryvyi Rih Iron Ore Region [10]. The analysis of the prevalence of oncological pathology among the residents of the Kryvyi Rih Iron Ore Basin provided the basis for identifying potential risk factors and their interrelations [3]. Importantly, mine water contamination represents one of the contributing factors.

To assess the prevalence of malignant neoplasms among the population, a cross-sectional epidemiological analysis was employed. The incidence of malignant

Table 1. Degree of groundwater pollution and ecological state of the natural environment

№	Degree of groundwater pollution	CPI (a.u.)	Ecological state of the natural environment
1	Conditionally clean	0 – 3	Favorable
2	Slightly polluted	3 – 10	Satisfactory
3	Moderately polluted	10 – 20	Strained
4	Heavily polluted	> 20	Critical

Source: compiled by the authors of this study

Table 2. The chemical parameters of mine water and the level of its contamination, M±m (n=63)

Water quality indicators	The current concentration (C), mg/dm³*	K_i, a.u.	Rating
Dissolved oxygen	7,68±0,04	1,92	low
BOD_5	8,10±0,18**	2,66	moderate
pH	7,74±0,17	0,87	low
Suspended solids	111,29±5,61**	240,13	very high
COD	318,95±12,09**	12,34	high
Dry residue	24172,57±1473,50**	19,3	high
Chlorides	11983,70±858,26**	40,66	high
Sulphates	936,84±24,14**	1,90	low
Ammonium nitrogen	0,89±0,07	0,21	low
Nitrites	0,32±0,02	0,12	low
Nitrates	9,70±0,24	0,19	low
Phosphates	0,063±0,001	3,17	moderate
Oil products	0,3±0,02	1,37	low
Total iron	0,3±0,01	5,73	moderate
Phenols	0,001±0,0001	1,0	low

Notes: M ± m – mean ± standard error; * — except pH; ** — exceeded the MAC
Source: compiled by the authors of this study

neoplasms among the population was examined through a retrospective epidemiological analysis of statistical reports from healthcare institutions over a five-year period [1].

To assess the potential impact of mine water contamination on the increased risk of malignant neoplasms among the population of the Kryvyi Rih Iron Ore Basin, we applied risk assessment methodologies aimed at determining the etiologic fraction (EF) attributable to the harmful factor, namely contaminated mine water.

For this purpose, data on the prevalence of malignant neoplasms among the population of the city of Kryvyi Rih were used and compared with the corresponding data from conditionally «ecologically clean» regions of Ukraine (Ternopil and Chernivtsi regions), where there is no underground mining of mineral resources and, consequently, the population is not exposed to contaminated mine waters. In addition, the prevalence of oncological pathology was analyzed across age groups 0–14, 15–17, and ≥18 years old.

The risk assessment was carried out in accordance with internationally accepted methods [11–13], with consideration of the following parameters: the probability of developing a malignant neoplasm (P), attributable risk (AR) (additional risk caused by water pollution), EF of water pollution in the incidence of malignant neoplasms, probability of exposure to a risk factor among residents (Pe), and odds ratio (OR) with a 95% confidence interval (CI).

ETHICS

All the research methods used were considered by the local ethics committee, in accordance with the ethical principles of the Declaration of Helsinki, and approved for the use during the organization and conduct of research. No patients participated in the studies.

FRAMEWORK

The study was conducted as a fragment of the scientific projects of the Separate Division "Scientific and Practical

Table 3. Mine water quality assessment according to the integral indices, M±m (n=63)

Integral indices	Value	Rating
CPI, a.u., M ± m	331,57±100,24	Heavily polluted, the ecological state of the environment is critical
WPI, a.u., M ± m	22,10±5,12	Extremely polluted (class VII)
CCC, %, M ± m	67±7 %	Over 10%, thus requiring the more detailed study

Notes: M ± m – mean ± standard error

Source: compiled by the authors of this study

Table 4. The risk of malignant neoplasms related to the mine water contamination in different age groups

Parameters	Age groups (years)		
	0-14	15-17	≥18
AR	0,000641	0,002273	0,010426
EF	81,9 %	94,3 %	59,6 %
P_e	0,001	0,002	0,018
OR (95% CI)	5,528 (3,423–8,925)	16,310 (5,927–44,888)	2,461 (2,309–2,622)

Source: compiled by the authors of this study

Medical Center of Occupational Health of Shupyk National Healthcare University of Ukraine" «Prevention of occupational diseases at employees of industrial enterprises» (state registration numbers 0124U003711; term: 2024–2025); and «Comprehensive assessment of the health state at employees of industrial enterprises by organizing and managing medical examinations» (state registration numbers 0124U003723); term: 2024–2025).

RESULTS

Mine waters are formed as a result of the infiltration of surface and groundwater into mining workings. As the water passes through these workings, it is exposed to varying levels of contamination; therefore, it cannot be discharged into natural water sources without treatment, nor used for technical purposes without appropriate processing [1].

According to the results of our own laboratory studies, the chemical composition of mine waters and the level of their contamination were examined (Table 2).

It has been revealed that the levels of chemical substances in the mine water (dissolved oxygen, pH, ammonium nitrogen, nitrites, nitrates, phosphates, oil products, total iron, phenols) are within acceptable limits (Table 2), and, if reused, will not have a negative impact on natural water bodies, the environment, or public health.

On the contrary, such parameters as BOD_5, suspended solids, COD, dry residue, chlorides, and sulphates significantly exceed the MACs (Table 2) and pose an additional risk to the population when entering natural water bodies used for consumption and domestic purposes.

The impact of pollutants on human health may occur in a combined manner – both directly and indirectly – through soil, food products, and other environmental pathways.

According to Table 2, mine water is severely polluted (class VI of the possible seven contamination classes). There are 11 substances consistently present in it: BOD_5, dissolved oxygen, suspended solids, COD, dry residue, chlorides, sulphates, phosphates, oil products, and total iron. Moreover, BOD_5, total iron, and phosphates have an average level of pollution, while COD, dry residue, and chlorides have a high level, and suspended solids have a very high level. Furthermore, the impact of such pollution on biological organisms corresponds to hazard class IV, the highest, for phenols, oil products, and total iron. These indicators require additional analysis.

The integral pollution coefficients were also calculated (Table 3).

The analysis of integral pollution coefficients indicated a tendency toward increasing pollution levels (Table 3).

According to the CPI value, the water is characterized as heavily polluted, and the ecological state of the natural environment as critical. WPI is characterized as extremely polluted (class VII). In addition, CCC is over 10% and requires more detailed study (Table 3).

Mine waters are drained into natural water bodies that are used for drinking and domestic purposes. The exceedance of MACs of chemicals in the mine water, along with the calculated integral coefficients of complex pollution, provided a basis for comparing malignant neoplasm incidence among the population of industrial regions with incidence among the population of «ecologically clean» regions.

Utilizing these data, the contribution of this water pollution level to the incidence of environmentally related diseases in the population was quantified, and age-specific health risks were evaluated (Table 4).

It was established that the risk for developing malignant neoplasms in Kryvyi Rih industrial region was 25,054 (95 % CI 25,010–25,098) and depended on the age of the population. Teenagers aged 15–17 have the highest risk for developing malignant neoplasms (OR 16,310 [95% CI 5,927–44,888). Children under the age of 14 hold the second place in this ranking (OR 5,528 [95% CI 3,423–8,925]). Adults (≥18 years old) have a lower risk of malignant neoplasms (OR 2,461 [95% CI 2,309–2,622]) (Table 4).

The data shows that children and adolescents were more affected, than adults, i.e. the EF of mine water pollution in the development of malignant neoplasms is 81,9% and 94,3%, respectively (vs. 59,6% in adults) (Table 4).

Consequently, the discharge of untreated mine water represents a significant risk, potentially increasing the incidence of malignant neoplasms in the population [10].

DISCUSSION

The environmental impact of mine water in the study area has gained increasing relevance and has been intensively investigated over the past 10 years. Numerous studies have addressed the formation and discharge of mine water across various basins both in Ukraine and throughout Europe [14, 15].

The incidence of malignant neoplasms shows an increasing trend. Globally, over 12,3 million new cases of malignant neoplasms are diagnosed each year, of which 7,6 million are fatal (according to the World Health Organization, 9,6 million deaths [16]). Worldwide, the annual incidence of cancer increases by 5–10% [5, 17]. In Ukraine, incidence has risen by 25% over the past ten years, with a steady annual increase of 2,6–3%, accompanied by a "younger" age profile of patients, reducing life expectancy by 3–3,5 years. This socio-economic phenomenon is further highlighted by the fact that 40% of patients are of working age [8, 17].

The rising global burden of oncological diseases is linked to water pollution, with mining activities playing a critical role in contaminating aquatic ecosystems with complex mixtures of established carcinogens. It contributes to the estimated 8–9% of general morbidity attributed cumulatively to environmental factors, such as air and water pollution. Studies from different continents confirm this severe health impact. For example, in Northern Chile, a population exposed to drinking water averaging 570 μg/L of arsenic for over a decade exhibited staggering excess bladder cancer mortality, with women recording an 820% increase and men a 600% increase compared to the expected rate. In China, population-level evidence from a cohort surrounding a metal-smelting area reported associations between long-term environmental cadmium and lead exposure and a significantly increased mortality rate from all cancers, indicating a link between metal contamination and adverse oncological outcomes [18].

Mine water, classified as "very polluted" (class VI) with persistent contamination, is discharged into surface water bodies. The primary pollutants include BOD_5, dissolved oxygen, suspended solids, COD, total dissolved solids, chlorides, sulfates, phosphates, petroleum hydrocarbons, and total iron. The ecological status of the natural environment is characterized as critical [12].

Following settling and treatment, the water enters rivers utilized for economic activities. Nevertheless, the ecological status of the environment remains strained, and the population consumes "moderately polluted" water of class III quality, which inevitably impacts public health. These observations are supported by both domestic and international studies, underscoring the significance of the issue [14, 16, 19]. Large-scale mapping in China revealed that unacceptable carcinogenic risks are present in over half of mining areas, particularly for adults exposed to mining-affected surface or groundwater, especially where acid mine drainage contributes to high heavy metal burdens [20].

The data obtained regarding the etiological proportion of risk from environmental pollution in the development of malignant neoplasms in the population (EF), which ranges from 59,6% to 94,3%, confirm previous studies and emphasize the urgency and necessity of implementing environmental monitoring and preventive measures, as highlighted by international research [16, 19]. The greatest impact of pollution is observed among children and adolescents, with the highest risk of developing cancer among adolescents aged 15–17 years.

The results of malignant neoplasm analysis in the population may be considered baseline data and will allow monitoring of both the qualitative and quantitative state of mine waters and the health status of the population. These findings will form the basis for assessing the excess risk associated with the use of mine water and for determining the risk categories of carcinogenic and non-carcinogenic effects, as well as for the development of effective technologies for the treatment and demineralization of mine water.

CONCLUSIONS

1. The analysis of laboratory data on mine water from

the industrially affected region of Ukraine (Kryvyi Rih Iron Ore Basin) revealed that the concentrations of substances exceed the MACs. According to CPI, the water is classified as heavily polluted, while the ecological state of the environment is assessed as critical.
2. The highest risk of developing malignant neoplasms was observed among adolescents aged 15–17 years (OR 16,310 [95% CI 5,927-44,888), followed by children under 14 years (OR 5,528 [95% CI 3,423-8,925]). In comparison, the adult population demonstrated considerably lower risk levels (OR 2,461 [95% CI 2,309-2,622]). The EF of malignant neoplasms risk attributable to environmental pollution was estimated at 59,6–94,3%.
3. Considering the concentrations of chemical substances in mine water and the analysis of malignant neoplasms health risks, new approaches are required for the development of preventive measures and strategies, taking into account all determinants, including the environmental factors.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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