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Features of the Medical and Environmental Assessment of the Carcinogenic Risk of Air Pollution of Industrial Centers

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Abstract*:*The limitation of traditional approaches to assessing environmental hazards for human health and the inability to establish direct causal relationships have led to the need for the development of probabilistic methods for assessing the harm caused to health, collectively referred to as risk analysis methods.

The article aims to determine and compare the information value of some modern criteria for assessing the carcinogenic risk of air pollution for the health of the urban population living in settlements with different industrial profiles.

The article defines theoretical approaches to the study of the category of risk and the main directions of research in the field of environmental risk assessment. Based on the analysis of the scientific literature and the determination of carcinogenic risk, the authors analyze the problems arising from the air pollution of industrial centers.

***Keywords*: medical and environmental assessment, environmental risk, air pollution, carcinogenic risk, carcinogenic substance.**

I. INTRODUCTION

The problem of oncological diseases is one of the most important issues in modern medicine. Its relevance is conditioned by the high level of morbidity and mortality due to this type of pathology, a large number of etiological factors for oncological diseases, as well as the lack of effective methods for early diagnosis and treatment of the disease.

The quality of the environment directly affects human health and well-being [1]. This is especially true for atmospheric air due to its ability to penetrate other environments and directly affect the human body. Every country in the world faces the problem of air pollution. As a result, there comes the question not only of solving these problems but primarily of determining the level of pollution. Today, air pollution is one of the most important environmental problems throughout the world. This issue is especially urgent for urban and industrial territories [2, 3].

Despite the evidence of the effect of carcinogens in polluted air on the cancer incidence rate of the population [4-6], we cannot obtain an exhaustive answer regarding the quantitative characteristics of their effects, losses and damages due to diseases and predict the state of health under the conditions of constant long-term exposure to carcinogenic factors by using traditional assessment methods (comparison of detected concentrations with maximal permissible concentration (MPC), the application of the zero risk concept, etc.). In recent years, other criteria have been increasingly used, in particular, the reference concentrations method and the risk assessment method.

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II. LITERATURE REVIEW

Today, the concept of risk does not have a clear definition. Not only is there no universally recognized system of terms in risk assessment, but the very need for such terminology is not recognized [7]. A set of specialized terms is widely used, of which "hazard" and "risk" are the most common ones. Attempts by different authors to consider these terms as synonyms or to give them a certain content, unfortunately, are mutually inconsistent. This kind of attitude towards these terms remains typical for the media and the press.

Researchers define hazard as a natural or man-made phenomenon, which can result in other phenomena or processes that can affect people, cause material damage and destroy the environment [8], or as the probability of occurrence of a phenomenon potentially capable of hurting people and causing material losses at a certain point in time within specific territories [9].

Thus, hazard is a fairly broad, comprehensive concept that encompasses the views of various scientific fields. B.K. Lyon and B. Hallcroft [10] emphasize that hazard is a qualitative concept, while risk is its quantitative measure, the hazard occurrence rate and possible losses that can be established by multiplying the probability (rate) of negative events by the amount of possible damage from it. Most experts in natural and man-made hazards give a similar definition to risk.

The main elements of modern risk assessment are hazard assessment and calculation of the probability of the negative impact of various levels of anthropogenic environmental factors, while risk is viewed as a probability of human and material losses or damage [11, 12].

In recent years, this approach has become mainstream in the interpretation of the terms "risk" and "hazard".

The definition of environmental risk, which is still interpreted ambiguously, is important for environmental research. Various researchers distinguish various types of risk, depending on the specific field of application of the concept of risk. Some authors refer to environmental risk problems not only as public health risk but also as some other types of risk.

V.N. Bashkin [13] distinguishes the following types of environmental risk: 1) risk of the destruction of natural systems; 2) public health risk; 3) risk of man-made systems application for a specific industrial enterprise; 4) natural resources management risk; 5) risk of natural disasters; 6) risk of the influence of regional military conflicts; 7) risk of environmental terrorism.

It is obvious that the assessment of the risk to public health due to the impact of negative environmental factors is a problem of medical and environmental analysis.

The understanding of risk assessment within this area is also diverse. Some researchers associate environmental risk with certain environmental factors and evaluate the risk to the health of an individual, that is, the likelihood of specific adverse effects originating from the environment. In other cases, environmental risk is considered as a concept defined at the population level.

The concept of risk to human health was formed only in the last decade. Initially, such concepts were applied only to situations related to accidents or disasters, for example, for the assessment of occupational health and safety risk during the liquidation of accidents, in the conditions of an unregulated working day, for military personnel, etc. Subsequently, the method began to be used to analyze the risk associated with exposure to environmental factors in normal conditions. These works assess the risk of developing certain diseases, including oncological ones, due to the influence of specific pathogenic agents [14-16].

Significant work on the development of this approach concerning environmental issues and the systematization of risk analysis methods has been carried out by the US Environmental Protection Agency (EPA). The EPA reports demonstrate risk analysis techniques for individual environmental factors, in particular, those that do not have an effect threshold (radionuclides, chemical carcinogens).

Despite the ambiguity of the concept and approaches to assessing environmental risk, today this area is one of the most promising ones and is developing rapidly. The very principle of risk analysis implies the emergence of derived concepts. Using this approach makes it possible to solve many problems in toxicology and hygienic regulation. Unlike toxic factors, carcinogenic factors do not have an explicit effect threshold that can be determined, which makes it impossible to establish a uniform hygienic standardization based on traditional approaches. The concept of risk can be used for both threshold toxic factors and non-threshold carcinogenic factors, which makes possible the convergence of two principles of hygienic regulation, i. e. the threshold- and non-threshold nature [17].

Risk assessment of long-acting environmental factors that can influence an individual in ordinary conditions, the health of the population as a whole or the health of large enough population groups remains a new and poorly studied aspect of hygiene science. The number of works on this topic is constantly increasing, but this problem remains poorly understood, despite its relevance.

Research hypothesis: the carcinogenic risk indicators will be of the greatest benefit when conducting a hygienic assessment of the effects of carcinogens in different territories, at different observation times, before and after taking any environmental or health-related measures.

III. PROPOSED METHODOLOGY

A. General description

The theoretical study was based on the use of systems analysis methods, as well as on the theories of international management and intercultural communications.

For the analysis, we selected the following cities of the Ural Federal District (UFD): Chelyabinsk (a city with enterprises primarily in the metallurgical industry), Tyumen (a city with enterprises primarily in the oil refining industry), Yekaterinburg (the largest city of the UFD and a large administrative center).

As an indicator substance, we studied such chemical compounds as benz(a)pyrene (BP) — an indicator of polycyclic aromatic hydrocarbons (PAH), nitrosamine(s), such as nitrosodimethylamine (NDMA) and nitrosodiethylamine (NDEA), formaldehyde, benzene and heavy metals (lead, chromium VI, nickel and cadmium). All these substances are classified by the IARC (International Agency for Research on Cancer) as carcinogenic to humans.

The work used data from monitoring of atmospheric air pollution by the FSBI “Ural Administration for Hydrometeorology and Environmental Monitoring” in 2016-2018.

To assess carcinogenic risk, we used the general procedure of the Human Health Risk Assessment methodology developed and recommended by the World Health Organization (WHO) and adapted to Russian conditions [18].

Besides that, we used the expert survey method to determine methods and approaches to solving the problems of the medical and environmental assessment of carcinogenic risk in the air pollution of industrial centers.

The survey was conducted online with the participation of 19 experts, among them 11 employees of the Russian meteorological service and 7 members of the university staff and teachers of the Department of Ecology.

B. Algorithm

At the first stage of the study, we carried out an analysis of the scientific literature on the problem of the medical and environmental assessment of carcinogenic risk in air pollution.

At the second stage of the study, we performed a comparative qualitative and quantitative study of the indicators for assessing the carcinogenic hazard of atmospheric air pollution for the health of the urban population living in settlements with different industrial profiles in the UFD,and an expert survey regarding problems directly related to medical and environmental assessment of carcinogenic risk in air pollution.

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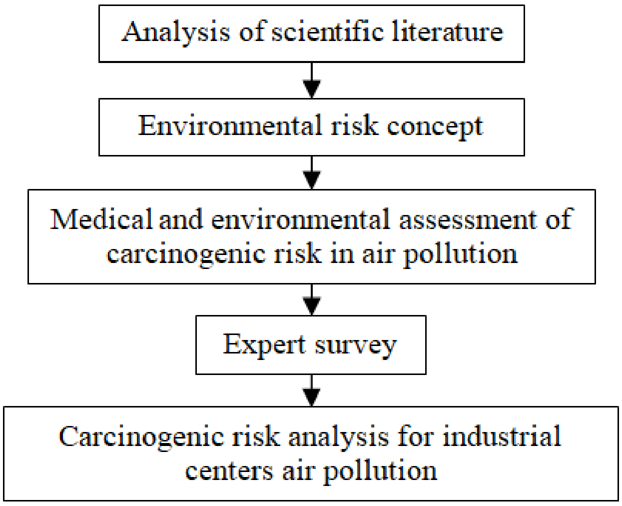
C. Flow chart



IV. RESULT ANALYSIS

Table 1 shows the data on the content of chemical carcinogens in the air of the studied settlements.

Analyzing the results and evaluating them according to the criterion of the average daily MPC, we should note that the excess of generally accepted hygiene standards was recorded only for individual carcinogenic compounds. First of all, this concerned such substances as BP, formaldehyde and nitrosamines, the content of which exceeded the maximum permissible concentrations by a factor of 1.5-6.9. As for benzene, its high content was observed only in Tyumen, where the chemical industry prevails. The content of other compounds, including heavy metals, fell within the MPC.

Table 1: Concentrations of priority chemical carcinogens in the atmospheric air of the cities of Chelyabinsk, Tyumen, Yekaterinburg

Carcinogen	Average daily concentrations (mg/m^3) of chemicals in the air*			Daily average MPC, mg/m^3	Reference concentration, mg/m^3
	Chelyabinsk	Yekaterinburg	Tyumen		
Benz(a)pyrene	$6{,}9 \times 10^{-6}$	$4{,}2 \times 10^{-6}$	$4{,}2 \times 10^{-6}$	1×10^{-6}	1×10^{-6}
Formaldehyde	0.008	0.006	0.011	0.003	0.003
Benzene	0.06	0.05	0.43	0.1	0.03
Cadmium	0.00007	0.00004	0.00003	0.0003	0.00002
Nickel	0.00013	0.00007	0.00012	0.001	0.00005
Lead	0.00051	0.0001	0.00015	0.0003	0.0005
Chromium VI	0.00015	0.00012	0.0002	0.0015	0.0001
Nitrosodimethylamine	0.0001	0.000072	0.000086	0.00005	none
Nitrosodiethylamine	0.000066	0.000044	0.000048	0.00001**	none

Note: * – average data of the annual cycle, ** – calculated MPC.

A completely different situation is observed if we compare the actual level of pollution in each of the studied settlements with a safe level of exposure, the equivalent of which is the reference concentration [7, 8]. Almost all identified compounds are characterized by hazard indices at levels above 1, which indicates their hazardous nature and the likelihood of developing harmful effects, which increases in proportion to the excess of this index (Table 2).

Table 2:Hazard indices of carcinogenic substances identified in the atmospheric air of the cities of Chelyabinsk, Tyumen, Yekaterinburg

Carcinogen	MPC excess ratio			The multiplicity of exceeding reference concentrations, HQ		
	Chelyabinsk	Yekaterinburg	Tyumen	Chelyabinsk	Yekaterinburg	Tyumen
Benz(a)pyrene	6.9	4.2	4.2	6.9	4.2	4.2
Formaldehyde	2.7	2	3.7	2.7	2	3.7
Benzene	0.6	0.5	4.3	2	1.7	14.3
Cadmium	0.23	0.13	0.1	3.5	2	1.5
Nickel	0.13	0.07	0.12	2.6	1.4	2.4
Lead	1.7	0.33	0.5	1.02	0.2	0.3
Chromium VI	0.1	0.08	0.13	1.5	1.2	2
Nitrosodimethylamine	2	1.44	1.7	-	-	-
Nitrosodiethylamine	6.6	4.4	4.8	-	-	-

To compare the degree of total atmospheric air pollution in settlements with a different industry profile, we used such a criterion as the total pollution indicator (the sum of the ratios of the real concentrations of compounds to their MPC taking into account the hazard class of the substance). Subject to hygiene standards for carcinogens taken into account, the permissible total pollution indicator is determined at 10.97. By this criterion, all indicated settlements are characterized by increased general pollution (Table 3).

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Table 3:Integral indicators of air pollution by carcinogens in the cities of Chelyabinsk, Tyumen, Yekaterinburg

Carcinogen	Integral Pollution Index			Permissible total
	Chelyabinsk	Yekaterinburg	Tyumen	
Benz(a)pyrene	8.62	5.25	5.25	1.25
Formaldehyde	2.96	2.22	4.07	1.11
Benzene	0.67	0.55	4.78	1.11
Cadmium	0.29	0.17	0.13	1.25
Nickel	0.16	0.09	0.15	1.25
Lead	2.12	0.41	0.62	1.25
Chromium VI	0.12	0.1	0.17	1.25
Nitrosodimethylamine	2.5	1.8	2.15	1.25
Nitrosodiethylamine	8.25	5.5	6.0	1.25
Σ	25.69	16.09	23.32	10.97

The air quality in the city of Chelyabinsk is the most hazardous one, with an integrated indicator of total pollution with carcinogenic substances at the level of 25.69. A slightly lower generalized indicator of pollution has been observed in Tyumen (23.32). The total air pollution in the city of Yekaterinburg equals 16.09. Moreover, the largest share of the contribution to the formation of total pollution is due to the level of concentration of substances such as BP, formaldehyde, nitrosamines, benzene and lead.

Thus, the indicators we determined indicate that the maximum permissible level of total pollution is exceeded by a factor of 1.46-2.34, depending on the nature of industrial development. Such a multiplicity of exceeding atmospheric air pollution indicators, according to experts, allows us to determine the existing level of the studied carcinogenic substances as unacceptable and its hazard degree as moderately hazardous (Chelyabinsk, Tyumen) or slightly hazardous (Yekaterinburg).

Analyzing the data presented, it is easy to notice that the applied evaluation criteria made it possible to characterize the quality of the air environment, which is important for solving environmental issues. Unfortunately, the issues of the qualitative and quantitative hazard of existing pollution directly to people remain open.

We tried to solve this problem by calculating the carcinogenic risks and hazards for individual compounds and their sum (Table 4).

Table 4:Carcinogenic risk of air pollution in the cities of Chelyabinsk, Tyumen, Yekaterinburg

Carcinogen	Aerogenic individual carcinogenic risk		
	Chelyabinsk	Yekaterinburg	Tyumen
Benz(a)pyrene	$7.6x10^{-6}$	$4.6x10^{-6}$	$4.6x10^{-6}$
Formaldehyde	$10.5x10^{-5}$	$7.9x10^{-5}$	$1.4x10^{-4}$
Benzene	$4.6x10^{-4}$	$3.9x10^{-4}$	$3.3x10^{-3}$
Cadmium	$12.6x10^{-5}$	$7.2x10^{-5}$	$5.4x10^{-5}$
Nickel	$3.1x10^{-5}$	$1.7x10^{-5}$	$2.9x10^{-5}$
Chromium VI	$1.8x10^{-3}$	$14.4x10^{-4}$	$2.4x10^{-3}$
Lead	$6.1x10^{-6}$	$1.2x10^{-6}$	$1.8x10^{-6}$
Nitrosodimethylamine	$1.4x10^{-3}$	$10.1x10^{-4}$	$1.2x10^{-3}$
Nitrosodiethylamine	$2.9x10^{-3}$	$1.9x10^{-3}$	$2.1x10^{-3}$
Σ	$6.8x10^{-3}$	$4.9x10^{-3}$	$9.2x10^{-3}$

The calculation of the individual carcinogenic risk (ICR) for each carcinogen that is ingested by inhalation was performed by multiplying the carcinogenic potential factor of the substance by the average daily dose of its effect on the human body (exposure); the total carcinogenic risk was determined by adding up the values of the ICR of each carcinogenic substance.

According to experts, the ICR of the inhalation effect of most substances (BP, lead, cadmium and nickel) on the urban population can be classified as low, the effect of which is insignificant and does not require any management interventions to reduce it (Table 4). As for other compounds (formaldehyde, benzene, chromium V, nitrosamines), the carcinogenic risk from their exposure is estimated by experts as average, which cannot be considered acceptable and requires dynamic monitoring and determination of sources with subsequent analysis of possible harmful effects. In general, according to experts, the data in Table 4 allow ranking the identified hazardous substances by carcinogenic risk, according to which, nitrosamines and chrome make the largest contribution to the total carcinogenic load, which forms a carcinogenic risk, and for conditions of Tyumen, also benzene. Determining the sources of these compounds in the environment, according to experts, argues the need to implement appropriate local risk management measures by reducing their release and the level of aerogenic load on the body.

Besides, the obtained data, according to experts, indicate the need for monitoring the content of these substances in the air of the studied cities, where these substances are the most common ones and can be viewed as pollution criteria.

In order to determine the social burden on the population living in the studied settlements from exposure to chemical carcinogens, it is possible to calculate the population carcinogenic risk, which reflects the additional (to the baseline) number of cases of neoplasms due to contact with these compounds, by multiplying the ICR by the size of the population that is influenced by this substance.

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V. DISCUSSION

In global practice, according to the experts participating in the survey, risk is most often assessed by mortality rates and cancer rates. However, the experts emphasize that, despite the importance of these criteria, they do not give the opportunity to fully assess the risk associated with the action of the whole complex of environmental pollutants.

International experience in risk assessment indicates the need to take into account those environmental pollutants that, without carcinogenic properties, can be significantly harmful and toxic to the population. The experts emphasize that many environmental factors that do not directly cause any changes in the body can serve as a baseline, which leads to increased sensitivity to other simultaneous or later effects, as well as a change in the nature or severity of the pathological process. Besides, non-cancer effects, unlike cancer, can be reversible. Some changes in the functional state of the body occur immediately, while others present later. This fact, according to the experts, makes it necessary to carefully take into account the time factor, in particular, the action of background factors, the direct influence of which is difficult to detect by itself. The task becomes even more difficult due to the fact that, as one of the respondents (Grigory N.) noted, "the range of changes in the state of health caused by the influence of environmental factors is very wide, from changes in the functional state and homeostasis of the body to chronic types of pathology".

Thus, according to the experts, the main directions of analyzing the risk to public health from environmental factors today are similar to those used in traditional epidemiological studies and are carried out both by assessing the influence of environmental factors (concentration of pollutants) and the effect of their impact on public health. To obtain adequate results, according to the experts interviewed, it is also necessary to take into account social, housing and material living conditions, the level of medical care and other biomedical factors.

Unfortunately, according to the experts, reliable methods for a comprehensive assessment of the simultaneous exposure to humans of many environmental factors, especially factors of a diverse nature, have not been developed so far, possibly due to the complexity of accounting methods and the very large total number of interrelated factors.

According to the experts, in environmental risk assessment studies today, the problems that are characteristic of all medical and environmental studies remain unresolved. In particular, this refers to the problem of extrapolating toxicological data to low levels, typical for real environmental situations. The problem of transferring data obtained in an experiment on animals to humans has not been resolved. Methodological approaches to accounting for the complex multifactorial nature of the influence of harmful environmental factors (effects of potentiation, synergism, etc.) have not been sufficiently developed.

At the same time, in spite of all the difficulties, the methods of environmental risk analysis developed today are an essential step necessary for understanding the mechanisms of the influence of harmful environmental factors on public health. The mathematical apparatus used can significantly increase the probability of the estimates obtained.

However, the problem of errors and inaccuracies, which are laid directly on the base of criteria, based on which the calculations are performed, has not yet been solved. An extremely urgent and undeveloped problem today is the creation of an adequate new base of criteria for risk analysis based on molecular level criteria used for population analysis.

VI. CONCLUSION

Finally, we can draw the following conclusions.

1. An analysis of the air environment of the cities under study showed significant stable atmospheric pollution in each of them with chemical carcinogenic compounds.

2. According to the MPC criterion and the integral indicator of total pollution, the most hazardous is the quality of atmospheric air in cities with a predominant metallurgical industry, while according to the risk criterion, the greatest hazard to the population has been calculated in cities with a predominant petrochemical industry.

3. The analysis of carcinogenic risk indicators showed that although the ICR of inhalation exposure of most substances can be classified as low or medium, the total carcinogenic risk that is created by the studied compounds is considered high for the health of the population living in these settlements, regardless of industrial profile of cities, and requires the adoption of measures to reduce it.

The results of the study confirmed the hypothesis that the carcinogenic risk indicators would be most useful when conducting a hygienic assessment of the effects of carcinogens in different territories, at different observation times, before and after any environmental or health-related measures.

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