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ASSESSMENT OF THE NON-CARCINOGENIC RISK TO POPULATION HEALTH FROM ATMOSPHERIC AIR POLLUTION IN DNIPROPETROVSK OBLAST

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ОЦІНКА НЕКАНЦЕРОГЕННОГО РИЗИКУ ДЛЯ ЗДОРОВ'Я НАСЕЛЕННЯ ВІД ЗАБРУДНЕННЯ АТМОСФЕРНОГО ПОВІТРЯ ДНІПРОПЕТРОВСЬКОЇ ОБЛАСТІ

Purpose. The purpose of this work is to assess the non-carcinogenic risk to population health from air pollution in Dnipropetrovsk Oblast.

The methods. Assessment of the non-carcinogenic risk to population health from air pollution in Dnipropetrovsk Oblast was carried out as follows: hazards were identified; dose-response relationships were assessed; priority air pollutants were ranked; and exposure was assessed using the methodology approved by the Ministry of Health of Ukraine.

Findings. The ranking of priority atmospheric air pollutants in Dnipropetrovsk Oblast according to the comparative non-carcinogenic hazard index (*HRI*), which takes into account the health impact weighting factor, the population size and the amount of conditional exposure to the substance, demonstrates that phenol has the lowest *HRI* value in the region with a value of 4,914,088, and dust has the highest value with an index of 1,788,636,286. Phenol has the highest value of the hazard coefficient, which characterises the risk of non-carcinogenic effects from air pollution in Dnipro city with a value of 5.78, indicating a high risk of negative impact on human health from its presence in the air. The overall hazard index of non-carcinogenic risk from air pollution in Dnipro is 16.03 and is characterised as extremely high.

Scientific novelty. The dependence of the distribution of pollutant and greenhouse gas emissions from stationary sources in the Dnipro region by districts of the region, taking into account the number of enterprises with relevant emissions, was further developed. The classification of priority air pollutants in the Dnipro region was improved according to the value of the comparative non-carcinogenic hazard index (HRI), which takes into account the weighting factor of the impact on health, population size and the value of the conditional exposure to a substance.

Practical implementation. The research results can help to reduce air pollution in Dnipropetrovsk Oblast. This will improve the quality of life of the local population and preserve the natural environment from negative impact. The research findings can also serve as a basis for developing and implementing strategies and programmes to reduce air pollution in the region. This will help the authorities to make effective and informed decisions in the field of environmental protection.

Keywords: *atmospheric air, pollutants, pollution, population health, non-carcinogenic risk, exposure, hazard classes.*

Introduction. Human health depends on many factors, such as genetics, social status, psychological state, availability and quality of medical care, lifestyle and presence of harmful habits, as well as living conditions and environmental quality. Determining the exact contribution of each of these factors to the diseases occurrence is often a difficult task due to the variety of possible influences, many of which may occur independently of these factors.

The study of the impact of atmospheric air pollution on the health of the population is extremely relevant in modern conditions, when environmental issues are becoming more and more acute. Risk assessment allows us to understand the real consequences of pollution for human health and to determine priorities in taking measures to reduce these risks. In connection with the man-caused load and industrialization of the Dnipropetrovsk Oblast, it is important to have a clear idea about the degree of hazard of air pollution for the population of the region.

Air pollution risk assessment helps to predict the probability and medico-social significance of possible health threats under different exposure scenarios, and also to establish the priority of risk factor management measures at the individual and population levels.

The development of ways to reduce the risk from atmospheric air pollution to population health reflects the importance of practical measures in the field of environmental protection and ensuring public health. Proposals and recommendations developed on the basis of the assessment results can serve as a basis for the development of new programs and strategies for environmental protection of the region. Such a work is a step in the direction of improving the quality of life of population and ensuring the sustainable development of the region.

Therefore, the **purpose of this study** is to assess the non-carcinogenic risk from atmospheric air pollution to the health of Dnipropetrovsk Oblast population.

Main body. A complete, or basic, scheme of risk assessment involves four interrelated stages, namely [1]:

1) hazard identification;
2) exposure assessment;
3) hazard characterization (dose-response assessment);
4) risk characteristics.

Hazard identification. The main goal of this stage is the selection of the key, most important chemical substances, the study of which will allow to assess the risks of impact on population health with sufficient accuracy and to determine their sources. The hazard identification process involves [2]:

– determination of all sources of environmental pollution and their possible impact on human;

– identification of all pollutants;

– analysis of the potentially harmful effects of chemical substances and assessment of the scientific basis for the possibility of these effects occurring in human;

– identification of priority chemical compounds for further study;

– establishment of harmful effects that may arise as a result of exposure to priority substances when evaluating routes of interaction (including contaminated environments and ways of penetration of chemicals into the human body), duration of exposure (acute, subacute, chronic, lifelong) and ways of their penetration into the human body (inhalation, oral, epidermal).

Identification of all sources of environmental pollution and their possible impact on human. Within the framework of this study, it is not possible to identify all sources of atmospheric air pollution in the region, however, we can analyze the contribution of the main pollutants of the air basin of the region according to the Regional report on the state of the natural environment in Dnipropetrovsk Oblast for 2022 [3–7]. The top ten enterprises of the region, which carry out the largest amount of emissions into the atmosphere, include PJSC ArcelorMittal Kryvyi Rih, JSC "YUZHNIY GOK" Mining and Processing Plant, DTEK Prydniprovska TPP, JSC Pokrovsk Mining and Processing Plant, PJSC Dnipro Metallurgical Plant, Public Utility "Dniprovodokanal", PC Kryvyi Rih iron ore plant, JSC Nikopol Ferroalloy Plant, PC Interpipe PRP, PJSC "Sukha Balka". That is, these are mainly enterprises of the metallurgical, mining, energy and public utility sectors.

The total amount of emissions in the region in 2021, according to the State Statistics Service of Ukraine, was 537,635.055 tons [8], and the largest contribution to the total emission was done by PJSC ArcelorMittal Kryvyi Rih with an indicator of 12.65%, followed by JSC "YUZHNIY GOK" Mining and Processing Plant (10.35%) and DTEK Prydniprovska TPP (6.66%).

There are also other participants who make a significant contribution to the pollution of the atmosphere in the region. This creates a problem for the quality of the environment and population health. Other enterprises also make a contribution, and their impact should also be considered for emission reduction measures.

In general, the largest polluting enterprises account for 55.58% of emissions from stationary sources of pollution in the region. Therefore, 44.42% are other objects of the region that were not included in this list.

As for the composition of emissions, the following substances were most often released into the atmosphere by regional enterprises: nitric oxide (in terms of nitrogen dioxide); sulfur dioxide; carbon monoxide; substances in the form of suspended solid particles (microparticles and fibers); metals and their compounds; non-methane volatile organic compounds (VOCs); manganese and its compounds; methane; iron and its compounds.

Somewhat less frequently, the following harmful substances were observed in emissions: chlorine and chlorine compounds; fluorine and its compounds; freon; sulfuric acid, etc.

Table 1 contains information on emissions of pollutants and greenhouse gases into the atmosphere from stationary sources in Dnipropetrovsk Oblast in 2021 according to the State Statistics Service of Ukraine [4].

According to the number of enterprises that had emissions into the atmosphere on the territory of the region, emissions of carbon monoxide (487 enterprises) and nitrogen compounds (487 enterprises) are the most common, which indicates the wide use of these substances in industry.

The largest emission by the number of tons is carbon dioxide (22,321,799.75 tons), which is associated with intensive industrial activity and fuel use. According to this indicator, Dnipropetrovsk Oblast ranks second in Ukraine, second only to Donetsk Oblast (22,699,514.65 tons).

Table 1

Emissions of pollutants and greenhouse gases into atmospheric air from stationary emission sources in 2021 in Dnipropetrovsk Oblast

Harmful substance	Number of enterprises that had emissions, units	Amount of emissions, tons
Carbon dioxide emissions	397	22,321,799.75
Carbon monoxide emissions	487	273,038.14
Methane emissions	317	121,972.69
Emissions of substances in the form of suspended solid particles	376	56,926.68
Emissions of dioxide and other sulfur compounds	250	55,293.46
Emissions of nitrogen compounds	487	27,970.28
Emissions of non-methane volatile organic compounds	310	1,668.74
Emissions of metals and their compounds	260	670.43
Emissions of fluorine and its compounds	99	29.27
Emissions of chlorine and its compounds	60	28.06
Cyanide emissions	13	14.94
Freon emissions	32	4.02
Emissions of persistent organic pollutants	14	0.81

Carbon monoxide (273,038.14 tons), methane (121,972.69 tons) and suspended solids (56,926.68 tons) also make an important contribution.

Dnipropetrovsk Oblast also ranks second in Ukraine in terms of atmospheric carbon monoxide pollution, behind Donetsk Oblast (297,054.233 tons). The situation is similar both with methane and with suspended solid particles.

According to the types of substances, carbon dioxide is emitted the most, which can be a key factor influencing the greenhouse effect and climate change. Carbon monoxide, methane and nitrogen compounds are also important because they can have a significant impact on air quality and population health.

The total volume of air emissions from stationary sources is significant, indicating the need to improve technologies and to implement measures to reduce emissions into the atmosphere.

Carbon dioxide and other greenhouse gases have potentially serious impact on climate change and require special attention in mitigation strategies. It is important to improve the monitoring and to control the emissions to ensure sustainable and environmentally safe development of the region.

If we analyze the territorial distribution of enterprises that emit pollutants and greenhouse gases into the atmosphere by Raions (Table 2), we can see that 77.5% of all emissions enter the atmosphere from three Raions of Oblast – Kryvyi Rih, Kamianske and Pavlohrad. The other 4 Raions of the region account for only 22.47% of emissions from stationary sources of pollution.

Atmospheric air is most intensively polluted by stationary sources of emissions in Kryvyi Rih Raion: 88 enterprises with emissions that make up 48.31% of the total number of emissions of enterprises in the region. Therefore, the emissions of the enterprises of this Raion make up almost half of all emissions of Dnipropetrovsk Oblast.

Table 2

Ranking of the Raions of Dnipropetrovsk Oblast by the amount of emissions into the atmosphere from stationary sources in 2021 [4]

Raion	The number of enterprises that had emissions of pollutants and greenhouse gases, units	The number of emissions of pollutants and greenhouse gases, tons	In % to the total emission in the region
Oblast in total	**531**	**537,635.055**	**100,0**
Raions of the Oblast			
Kryvyi Rih Raion	88	259,711.320	48.31
Kamianske Raion	80	88,190.713	16.40
Pavlohrad Raion	42	68,937.453	12.82
Synelnykove Raion	48	53,751.979	10.00
Nikopol Raion	42	34,215.126	6.36
Dnipro Raion	196	30,813.989	5.73
Novomoskovsk Raion	35	2,014.475	0.37

In terms of the number of enterprises that had emissions of pollutants and greenhouse gases into the air, Dnipro Raion occupies the first place – 196 units, but the contribution of these enterprises to the total volume of emissions is only 5.73%.

Thus, emissions in Oblast are marked by a significant distribution between different Raions, the main contribution of which falls to Kryvyi Rih Raion. It is necessary to pay attention to enterprises in Raions with large volumes of emissions and to consider the possibilities of reducing the negative impact on the environment.

Identification of all pollutants. Within the scope of this study, it is not possible to identify all pollutants, however, we have a list of the main harmful substances emitted into the atmosphere by enterprises of the region, which is given in Table 3 [3].

Analyzing Table 3 regarding the classes of hazard and human exposure conciderations of various harmful substances in the air of the working area as part of emissions from stationary sources in Dnipropetrovsk Oblast, the following conclusions can be drawn.

Most of the substances have medium hazard (3d class). Cyanides (1st and 2nd class), as well as chlorine and sulfur dioxide (2nd class) are the most dangerous among the considered substances. Carbon monoxide and methane are assigned to 4th class, which indicates their low level of hazard.

Table 3

Classes of hazard and maximum permissible concentrations of air-polluting materials within emissions from stationary sources in Dnipropetrovsk Oblast [5]

Air-polluting material	CAS	Maximum permissible concentration, mg/m^3	Preferential aggregative state	Class of hazard	Human exposure considerations
Carbon dioxide	124-38-9	8000	steam, and or gas	3	
Carbon monoxide	630-08-0	20	steam, and or gas	4	acute mechanism of action
Methane	74-82-8	7 000	steam, and or gas	4	
Solid particles	14808-60-7	1–4	aerosol	3	fibrogenic action
Sulfur dioxide	7446-11-9	1	aerosol	2	irritating action
Nitric oxide	11104-93-1	5	steam, and or gas	3	acute mechanism of action; irritating action
Nitrogen dioxide	10102-44-0	2	steam, and or gas	3	acute mechanism of action; irritating action
Chlorine	7782-50-5	1	steam, and or gas	2	acute mechanism of action; irritating action
Allyl cyanide	109-75-1	0,3	steam, and or gas	2	acute mechanism of action
Benzyl cyanide	140-29-4	0,8	steam, and or gas	2	acute mechanism of action
Hydrogen cyanide	74-90-8	0,3	steam, and or gas	1	acute mechanism of action
Metallic iron	7439-89-6	10	aerosol	4	fibrogenic action

Most of the substances have an acutely directed mechanism of action, which can lead to negative health consequences when received in significant concentrations. Solid particles have a fibrogenic effect, which can cause the development of diseases of the respiratory tract and lungs. Sulfur dioxide and chlorine have an irritating effect on the body, which can lead to various problems with the respiratory system. Cyanide substances also have an acutely directed mechanism of action, which can be dangerous for human health.

Understanding the hazard class and specifics of action of each harmful substance is important to determine the level of risk to the health of workers and population in general. It is necessary to take measures to control and to limit emissions of these substances to prevent negative consequences for health and the environment.

Determination of priority chemical compounds for further study. In accordance with the "Procedure of state monitoring in the field of atmospheric air protection" [6], subjects of atmospheric air monitoring establish observation points, monitor the levels of pollutants and the content of components and/or indicators of atmospheric precipitation according to the following list: 1. Sulfur dioxide. 2. Nitrogen dioxide and nitrogen oxides. 3. Benzol. 4. Carbon monoxide. 5. Lead. 6. Solid particles $(SP_{10})^{-1}$. 7. Solid particles $(SP_{2,5})^{-2}$. 8. Arsen. 9. Cadmium. 10. Mercury. 11. Nickel. 12. Benz(a)pyrene. 13. Ozone.

The subjects of atmospheric air monitoring are the Ministry of Environmental Protection and Natural Resources of Ukraine, Ministry of Health of Ukraine, State Service of Ukraine for Emergency Situations, State Agency of Ukraine for Exclusion Zone Management, the executive body of the Autonomous Republic of Crimea on issues of environmental protection, regional councils, Kyiv City State Administration, executive bodies of city councils.

Regarding air quality monitoring in the territory of Dnipropetrovsk Oblast, the basic network of monitoring the state of atmospheric air in residential areas consists of 15 automated stationary air quality analysis stations, which are on the balance sheet of the Public Utility "Environmental Monitoring Center" of the Dnipropetrovsk Regional Council.

Also, the basic network of atmospheric air monitoring in residential areas includes 15 non-automated stationary atmospheric air monitoring stations, belonging to the Dnipropetrovsk Regional Center for Hydrometeorology.

According to the approved data transfer regulations, the frequency of providing information to the department is:

– from the Public Utility "Environmental Monitoring Center" of the Dnipropetrovsk Regional Council" – every week;

– from the Dnipropetrovsk Regional Center for Hydrometeorology – every decade.

Since 2019, the server, which is on the balance sheet of the PU "Environmental Monitoring Center" of the Dnipropetrovsk Regional Council, has been undergoing maintenance. Therefore, the analysis of the state of atmospheric air pollution in the cities of Dnipropetrovsk Oblast is carried out only according to the data of the Dnipropetrovsk Regional Center for Hydrometeorology.

According to the data of the Dnipropetrovsk Regional Center for Hydrometeorology [7], in Dnipropetrovsk Oblast, in the cities of Dnipro, Kamianske and Kryvyi Rih, the following substances are monitored: dust; sulfuric anhydride; carbon monoxide; nitrogen dioxide; nitrous oxide; phenol; ammonia; formaldehyde and hydrogen sulfide.

Therefore, attention is paid to monitoring and controlling the levels of these substances in the air to ensure a healthy and safe environment for cities dwellers. Such analysis helps to identify potential air pollution problems and take measures to solve them. Accordingly, within the scope of our research, we will consider these substances as priorities for Dnipropetrovsk Oblast for further study.

Ranking of priority air pollutants. The following methods are used for preliminary ranking of chemicals [2]:

– information on the volume of emissions of chemical substances into the environment and the number of the population exposed to the influence;

– results of the pollutants distribution modeling (if there are appropriate automated software tools) and features of their behavior in the environment;

– monitoring data on the content of chemical compounds in various environmental objects;

– information about adverse effects caused by the chemical;

– values of reference exposure levels (hygienic standards, reference doses and concentrations, regional minimum risk levels and target concentrations);

– assignment of a chemical substance to the lists of priority hazardous or specially regulated chemical compounds.

For the preliminary ranking of substances that do not have a carcinogenic risk (systemic toxicants), the weighting factors based on safe doses or concentrations (TW) are used [2]:

$$HRI = \frac{E \cdot TW \cdot P}{10000}, \quad (1)$$

where *HRI* – comparative noncarcinogenic hazard index; *TW* – health impact weight factor; *P* – population size; *E* – amount of conditional exposure (tons/year).

Table 4 shows the reference (safe) concentrations of priority non-carcinogenic chemicals for Dnipropetrovsk Oblast.

Figure shows the ranking of priority air pollutants of Dnipropetrovsk Oblast according to the comparative non-carcinogenic hazard index (*HRI*), which takes into account the health impact weighting factor, the population size and the amount of conditional exposure to the substance. The population of Dnipropetrovsk Oblast as of January 1, 2021 was taken as 3,142,000 people [8].

In general, analyzing the obtained results, it can be concluded that among the priority air pollutants of the Dnipropetrovsk region, sulfur dioxide and dust have the highest level of non-carcinogenic hazard, that is, their presence in the air poses the greatest threat to population health. Phenol and nitrogen oxide have the lowest *HRI* indices, which may indicate a lower degree of hazard from these pollutants.

The smallest value of the HRI index has phenol with a value of 4,914,088, and the largest – dust with an index of 1,788,636,286. Substances with an average hazard index level can be identified by comparing the *HRI* index values for each substance. In this case, ammonia and carbon monoxide can be considered as substances with an average level of hazard.

Table 4

Reference (safe) concentrations of priority non-carcinogenic chemicals for Dnipropetrovsk Oblast

Substance	CAS	*RfCi*, mg/m^3	Source*	Critical organs/systems
Dust	14808-60-7	0.15**	MHU	Respiratory organs
Sulfuric anhydride	7446-09-5	0.08	NAAQS	Respiratory organs
Carbon monoxide	630-08-0	3.0	MO3	CNS, cardiovascular system, blood
Nitrogen dioxide	10102-44-0	0.04	WHO	Respiratory organs
Nitrous oxide	11104-93-1	0.06**	MHU	Respiratory organs
Phenol	108-95-2	0.006	EPA	Cardiovascular system, kidneys, CNS, liver
Ammonia	7664-41-7	0.1	IRIS	Respiratory organs
Hydrogen sulfide	7783-06-4	0.008**	MHU	Respiratory organs, CNS

Note: *WHO – World Health Organization; IRIS – integrated risk information system (U.S.EPA); NAAQS – National Ambient Air Quality Standards; EPA – publications of the United States Environmental Protection Agency; MHU – Ministry of Health of Ukraine

**average daily maximum allowable concentration according to hygienic regulations for permissible content of chemical and biological substances in the atmospheric air of populated areas [9]

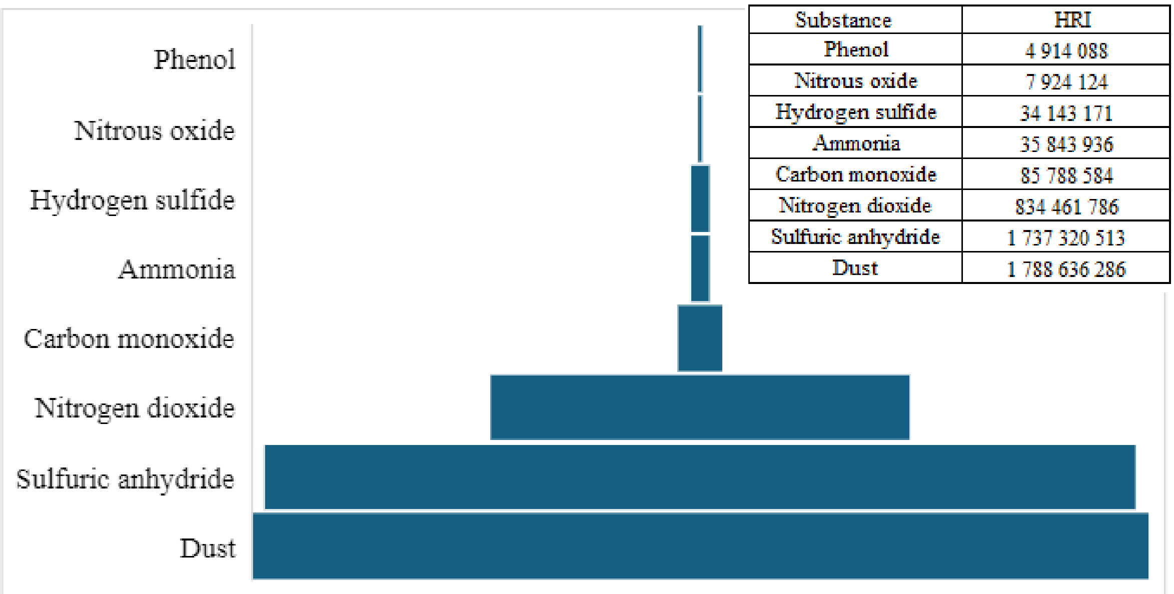

Fig. Ranking of priority air pollutants of Dnipropetrovsk Oblast according to the comparative non-carcinogenic hazard index *HRI*

Evaluation of exposure. This is the stage of risk assessment, during which the quantitative entry of the agent into the body through various ways of contact with various environmental objects is determined [2].

The calculation of intake involves the quantitative assessment of exposures for each chemical substance with specific routes of exposure. Estimated intake of substances are expressed in units of mass of a chemical compound in contact with a unit of human body mass, and have a dimension of mg/(kg·day).

The intake of chemical substances is usually calculated using formulas that take into account the influencing concentrations, the amount of contact, the frequency and duration of exposure, body weight and the exposure averaging time.

The result of this stage of risk assessment is the determination of the average daily dose (ADD/LADD), the formula for its calculating under the inhalation effect of a substance from atmospheric air has the form [2]:

$$ADD = \frac{\left[\left(C_a \cdot T_{out} \cdot V_{out}\right) + \left(C_h \cdot T_{in} \cdot V_{in}\right) \cdot EF \cdot ED\right]}{DW \cdot AT \cdot 365}, \quad (2)$$

where *ADD* – average daily dose of the substance, mg/kg·day; C_a – concentration of the substance in atmospheric air, mg/m^3; C_h – concentration of the substance in the air of the room, mg/m^3; T_{out} – time spent outdoors, h/day; 8 h/day; T_{in} – time spent indoors, h/day; 16 h/day; V_{out} – the rate of breathing outside the room, m^3/hour; 1,4 m^3/hour; V_{in} – the rate of breathing in the room, m^3/hour; 0,63 m^3/hour; *EF* – exposure frequency, days/year; 350 days/year; *ED* – duration of exposure, years; 30 years old, children – 6 years old; *BW* – body weight, kg; 70 kg, children – 15 kg; *AT* – exposure averaging period, years; 30 years, children – 6 years, carcinogens – 70 years.

Data from the Dnipropetrovsk Regional Hydrometeorology Center on the state of atmospheric air pollution in Dnipro city for 2023 were used to determine the average concentration of chemicals in atmospheric air affecting the exposure period [10]. Based on these data, the average daily dose of chemicals for inhalation exposure was calculated (Table 5). The results of the calculations are shown in Table 6.

The highest value of the average daily dose (ADD/LADD) is carbon monoxide with a value of 0.644 mg/kg·day, and the lowest is observed for phenol with a value of 0.001 mg/kg·day. These results give an idea of the level of exposure of harmful substances to human health by inhalation. Formulation of appropriate conclusions and recommendations for reducing exposure to these substances can be based on comparison with acceptable levels of exposure, safety limits and other factors affecting health.

Characterization of non-carcinogenic risk to population health. Characterization of the risk of the development of non-carcinogenic effects for individual substances is carried out on the basis of the calculation of the hazard ratio (*HQ*) according to the formula [2]:

$$HQ = \frac{AC}{RfC}, \quad (3)$$

where *HQ* – hazard ratio; *AC* – average concentration, mg/m^3; *RfC* – reference (safe) concentration, mg/m^3.

Table 6 shows the results of calculating the *HQ* hazard ratio for various pollutants in the air of Dnipro city.

Phenol has the highest hazard ratio with a value of 5.78, which indicates a high risk of adverse effects on human health due to its presence in the air. Also hydrogen sulfide has a high value of the risk coefficient, it is 5.17. These substances require special attention and possible measures to reduce their emissions or control their concentration in the air.

Ammonia has the lowest hazard ratio with a value of 0.02, indicating a lower potential risk of this substance affecting human health. Also, a small value of the risk coefficient is observed in the case of sulfuric anhydride – 0.14. The overall hazard index is 16.03.

The levels of acceptability of non-carcinogenic risks are ambiguously interpreted by different authors. On the one hand, the situation with *HQ* > 1 is not necessarily associated with the development of a harmful effect: the higher is the effective dose and the more it exceeds the reference dose, the higher will be the probability of harmful reactions. On the other hand, the risk at the level of *HQ* = 1 cannot be considered as quite acceptable.

Table 5

Average daily dose (ADD/LADD) for inhalation exposure to harmful substances from the atmospheric air of Dnipro city

Substance	$C_a = C_h$, mg/m^3	T_{out}, h	V_{out}, m^3/h	T_{in}, h	V_{in}, m^3/h	*EF*, days/year	*ED*, years	*BW*, kg	*AT*, years	*ADD/LADD*, mg/kg·day
Dust	0.265	8	1.4	16	0.63	350	30	70	30	0.077
Sulfur dioxide	0.01125	8	1.4	8	1.4	350	30	70	30	0.003
Carbon monoxide	2.1	8	1.4	8	1.4	350	30	70	30	0.644
Nitrogen dioxide	0.072333	8	1.4	8	1.4	350	30	70	30	0.022
Nitrous oxide	0.039	8	1.4	8	1.4	350	30	70	30	0.012
Hydrogen sulfide	0.034667	8	1.4	8	1.4	350	30	70	30	0.011
Phenol	0.00215	8	1.4	8	1.4	350	30	70	30	0.001
Ammonia	0.041333	8	1.4	8	1.4	350	30	70	30	0.013
Formaldehyde*	0.01365	8	1.4	8	1.4	350	70	70	70	0.004

*Note – carcinogen

Table 6

Results of the calculation of the risk of the development of non-carcinogenic effects from atmospheric air pollution in Dnipro city

Substance	CAS	*AC*, mg/m^3	*RfCi*, mg/m^3	*HQ*
Dust	14808-60-7	0,265	0,15	1,77
Sulfuric anhydride	7446-09-5	0,01125	0,08	0,14
Carbon monoxide	630-08-0	2,1	3	0,70
Nitrogen dioxide	10102-44-0	0,07233333	0,04	1,81
Nitrous oxide	11104-93-1	0,039	0,06	0,65
Phenol	108-95-2	0,03466667	0,006	5,78
Ammonia	7664-41-7	0,00215	0,1	0,02
Hydrogen sulfide	7783-06-4	0,04133333	0,008	5,17
Hazard index *HI*				**16,03**

**average daily maximum allowable concentration according to hygienic regulations for permissible content of chemical and biological substances in the atmospheric air of populated areas [9]

According to the existing classification [2], the calculated non-carcinogenic risk from atmospheric air pollution in Dnipro city is characterized as extremely high and requires significant attention and control to ensure the safety of citizens' health.

Conclusions. The priority chemicals for Dnipropetrovsk Oblast to monitor and control the levels of these substances in the air in order to ensure a healthy and safe environment for city residents are dust, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrous oxide, phenol, ammonia, formaldehyde and hydrogen sulfide. Among these pollutants, only formaldehyde has carcinogenic properties.

The ranking of priority air pollutants of Dnipropetrovsk Oblast according to the index of comparative non-carcinogenic hazard (*HRI*), which takes into account the weighting factor of the impact on health, the size of the population and the amount of conditional exposure to the substance, showed that the smallest value of the HRI index has phenol with a value of 4,914,088, and the largest – dust with index 1,788,636,286. Ammonia and carbon monoxide can be considered substances with an average level of hazard. Therefore, among the priority atmospheric air pollutants of Dnipropetrovsk Oblast, sulfur dioxide and dust have the highest level of non-carcinogenic danger, i.e. their presence in the air poses the greatest threat to the health of the population. Phenol and nitrogen oxide have the lowest *HRI* indices, which may indicate a lower degree of danger from these pollutants.

The results of the calculation of the risk of the development of non-carcinogenic effects from atmospheric air pollution in Dnipro city showed that phenol has the highest hazard ratio with a value of 5.78, which indicates a high risk of negative effects on human health as a result of its presence in the air. Hydrogen sulfide also has a high hazard ratio, it amounts 5.17. These substances require special attention and possible measures to reduce their emissions or control their concentration in the air. The overall hazard index is 16.03. According to the existing classification, the calculated non-carcinogenic risk from atmospheric air pollution in Dnipro city is characterized as extremely high and requires significant attention and control to ensure the safety of citizens' health.

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АНОТАЦІЯ

Мета. Метою роботи є оцінка неканцерогенного ризику для здоров’я населення від забруднення атмосфери Дніпропетровської області.

Методика. Оцінку неканцерогенного ризику для здоров’я населення від забруднення атмосфери Дніпропетровської області проводили наступним чином: визначено джерела забруднення; оцінено залежність «доза-ефект»; ранжовано пріоритетні забруднювачі повітря; проведено оцінку експозиції за методикою, затвердженою МОЗ України.

Результати. Ранжування пріоритетних забруднювачів атмосферного повітря Дніпропетровської області за індексом порівняльної неканцерогенної небезпеки (HRI), який враховує ваговий коефіцієнт впливу на здоров'я, чисельність популяції та величину умовної експозиції речовини демонструє, що найменше значення індексу HRI у області має фенол з величиною 4 914 088, а найбільше – пил з індексом 1 788 636 286. Найбільше значення коефіцієнта небезпеки, який характеризує ризик розвитку неканцерогенних ефектів від забруднення атмосферного повітря у м. Дніпро має фенол зі значенням 5,78, що вказує на високий ризик негативного впливу на здоров'я людей від його присутності у повітрі. Загальний індекс небезпеки неканцерогенного ризику від забруднення атмосферного повітря у м. Дніпро становить 16,03 і характеризується як надзвичайно високий.

Наукова новизна. Дістала подальшого розвитку залежність розподілу кількості викидів забруднюючих речовин і парникових газів в атмосферне повітря від стаціонарних джерел

викидів у Дніпропетровській області за районами області з урахуванням кількості підприємств, які мали відповідні викиди. Удосконалена класифікація пріоритетних забруднювачів атмосферного повітря Дніпропетровської області за величиною індексу порівняльної неканцерогенної небезпеки (HRI), який враховує ваговий коефіцієнт впливу на здоров'я, чисельність популяції та величину умовної експозиції речовини.

Практична значимість. Результати досліджень можуть сприяти зменшенню рівня забруднення атмосферного повітря у Дніпропетровській області. Це дозволить покращити якість життя місцевого населення та вберегти природне середовище від негативного впливу. Результати досліджень також можуть слугувати основою для розробки та впровадження стратегій та програм зменшення забруднення атмосферного повітря в області. Це допоможе органам влади приймати ефективні та обґрунтовані рішення у сфері охорони навколишнього середовища.

Ключові слова: *атмосферне повітря, забруднюючі речовини, забруднення, здоров'я населення, неканцерогенний ризик, вплив, класи небезпеки.*