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Risk assessment for public health from air pollution in the industrial regions of Ukraine

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ABSTRACT

The main purpose of the research is to improve the efficiency of management decisions in the field of environmental protection through using the methods for assessing the public health risk at the current level of air pollution.

Methodology. The article presents a hierarchical methodological approach for determination of the level of air pollution hazard at the state, regional and local levels.

The state of atmospheric air is greatly affected by emergencies associated with accidents at chemically hazardous facilities, which result in burst releases of hazardous chemicals into the environment. When determining the environmental risk of deterioration in the state of atmospheric air, the chemical hazard indicator was taken into account.

Results. On the territory of the East of Ukraine there is the largest number of potentially dangerous enterprises. A new methodology of determination of the hazard level of air pollution is presented at the existing trends of anthropogenic load and the possible occurrence of technogenic emergencies. Assessment of public health risk due to air pollution in the Mariupol city showed an extremely high level of danger.

The determination of the risk as a macroecological indicator according to the new method shows a high level of hazard of air pollution in the industrial developed regions of Ukraine. The shortcomings of the methodical approach of the United States Environmental Protection Agency (EPA US), widely used in many countries of the world, are shown. An analysis of methodological approaches to assessing the public health risk has shown the promise of using the methodology for assessing potential risk in determining the level of environmental hazard of industrial enterprises. The assessment of the public health risk in the current quality state of air is given by two different methods for the regions of Ukraine with a high level of ecological and chemical hazard.

The improvement of the methodology for assessing the risk to public health due to air pollution is proposed, which is presented as a **scientific novelty**. Currently when Ukraine has been affected by hostilities and the economic crisis, the issue of priority funding for environmental protection is very important. The implementation of the proposed methodological approach will make it possible to scientifically determine regions with an increased level of hazard to public health and minimize financial resources for improving the air quality, which has actual **practical significance**.

Keywords*: air, emergencies, chemical hazard, risk, public health, pollutant emissions, industrial regions of Ukraine.*

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1. Introduction

Atmospheric air pollution is one of the world's major environmental problems. Polluted air affects human health, flora and fauna, soil acidification, nutrient availability and water chemistry, the composition and function of ecosystems, and corrosion of materials (Ashmore M. et al., 2012). The harmful effects of air pollution also include climate change, degradation of ecosystems due to acid rain, ozone depletion, global warming (Manisalidis I. et

al., 2020). The impact on health is more intense in cities with significant sources of emissions, unfavorable climatic characteristics and high population density. Many health problems, such as eye irritation, respiratory diseases, allergies, etc., can be directly related to exposure to polluted air (Gupta U.,. et al., 2012).

At the present stage, the socio-economic development of society is in direct correlation with the quality of the environment. The unfavorable ecological situation was the cause of many chronic diseases. The decline in fertility and an increase in mortality in recent years has led to a sharp deterioration of the demographic situation in Ukraine.

Ensuring stable social development necessitates the development of tools for assessing the level of environmental safety in order to determine the allowable anthropogenic load and reduce morbidity, so the study of this work is relevant.

According to the World Health Organization, 92% of the world's population lives in places where air quality exceeds the recommended limits. Ukraine has recently seen the highest number of deaths per 100,000 people (from 120 countries) due to air pollution (Popov O., Iatsyshyn A. et al., 2020).

For financial resources management and implementation of environmental measures and prevention of emergencies, this is a very relevant task. A comparison of methodological approaches to assess the risk for public health from air pollution has a scientific focus.

2. Analysis of Reference Data and Problem Statement

In many countries of the world, the use of risk assessment approaches for public health for the purposes of socio-hygienic monitoring, environmental and hygienic examinations, ecological audits, determination of environmental disaster zones and environmental emergency situations, state ecological control, substantiation of environmental and health action plans of the population is enshrined in law. The results of risk assessment allow us to determine the appropriateness, priority and effectiveness of environmental and sanitation measures aimed at reducing the adverse impact of the environment on public health.

Polluted air has the greatest impact on diseases of the respiratory system. The authors of (Singh R. B., Grover A. 2018). made a spatio-temporal analysis for three urban regions, rural area and for the city of Delhi on the incidence of air pollution. The results of the analysis showed that diseases tend to worsen as the level of air pollution increases. This study is important for Delhi residents and shows the need to monitor air quality and reduce pollutant emissions, but this method cannot be proposed to determine the risk to public health, because the risk is the probability of an event that is not discussed in this article.

The authors of article (Pospelov B., Kovrehin V. et al., 2020). developed a method for detecting dangerous conditions of polluted air in urban areas in real time for any amount of pollutants. The method is based on the restoration of the latent dynamics of the total risk of instantaneous action on the basis of current measurements of the concentration of pollutants at the control point. The use of the developed method in several control points would allow to determine the spatio-temporal distribution of the levels of the total risk of instantaneous effects of air pollution on the population within the territory (Pospelov B., Kovrehin V. et al., 2020).

Article discusses the important role of risk assessment in emergency and disaster management. The risks that are most important for emergency management include: (1) the probability of the existence or occurrence of a health hazard; (2) the probability that the hazard will occur; (3) the probability that the event will cause harm to health; (4) the probability that harm to health will increase the incidence of the population. Authors of (Arnold J. L., 2012). believe that the overall risk of deteriorating public health is the result of these four probabilities. Atmospheric air pollution, of course, is one of the causes of human disease, so in this case, it is enough to determine the probability of deterioration (or increase) in morbidity.

Risk assessments are tools that help systems at risk (medical organizations, communities, regions, states and countries) to develop rational risk reduction strategies (Arnold J. L., 2012).

The authors of the article (Popov O., Iatsyshyn A. et al., 2020). based on official statistics and data from state monitoring identified and analyzed the risks to the health of the population of Kyiv associated with air pollution. The following methods were used: systematic, functional and comparative analysis, risk theory, mathematical modeling, probability theory and mathematical statistics, as well as geographic information technology technologies for digital map design and targeted methodology for software design systems.

The paper (Pospelov B., Andronov V. et al., 2020) presents a mathematical model of joint determination of risk to human health and detection of dangerous conditions of polluted urban atmosphere to measure the current concentrations of pollutants. A feature of the model is the use only the measurement of current concentrations of pollutants in the atmosphere at the control point without taking into account meteorological information.

The monograph (Васенко О.Г. та ін., 2015). presents a method of a comprehensive assessment of the ecological status of surface waters, air, soils and land resources of the region and a method of determining the ecological risk of disturbance of natural

ecosystems while maintaining existing trends in anthropogenic pressure for further use in environmental management. The advantage of this method is the use of official monitoring data on the state of the components of the environment and their sources of pollution.

But, the method of determining the ecological risk of disruption of natural ecosystems does not take into account the source of emergencies, which is a very important factor in the deterioration of the environment and the deterioration of public health and even death.

Emergencies can occur due to significant air pollution due to technological disruptions or adverse weather conditions, or unauthorized emissions. The article (Popov O., Taraduda D.et al., 2020) presents the structure of new information and technical methods of emergency prevention. This paper describes the most likely occurrence and development of emergencies related to the entry of toxic substances into the atmosphere at potentially dangerous objects (Popov O., Taraduda D.et al., 2020).

It should be noted that during January-June 2020 in Ukraine as a result of emergencies 1241 people died (including 15 children) and 43873 people were injured (including 3299 children). The largest number of emergencies occurred in Donetsk, Dnipropetrovsk and Luhansk regions, due to the wear and obsolescence of technological equipment of industrial enterprises, especially at environmentally and chemically dangerous sites. In Donetsk and Luhansk regions, the situation is exacerbated by hostilities.

Fighting leads to pollution of environmental components and emergencies. A feature of Donetsk and Luhansk regions is the presence of a large number of objects of high man-made danger, which due to the anti-terrorist operation (ATO) are at risk of explosions, damage and other emergencies, which leads to chemical contamination of soil, air, surface and groundwater.

During the anti-terrorist operation (ATO) from 2014 to 2017, more than 500 emergencies were recorded at the enterprises of the region, which had an impact on the environment and the population (Environmental Assessment and Recovery Priorities for Eastern Ukraine, 2017).

Therefore, we believe that it is necessary to improve the method of determining the level of danger of air pollution under the modern influence of point and mobile sources of pollution, taking into account the risk of chemical and man-made emergencies.

An analysis of state regulatory documents in the field of technogenic and ecological safety of the impact of industrial enterprises on the environment and public health showed their imperfection and the need to adapt to the requirements of European ecological legislation.

In Ukraine, there are guidelines MR 2.2.12-142-2007 "Assessment of the risk to public health from air pollution", which are based on the American methodological approach to determining the risk to public health (Integrated Risk Information System). The disadvantages of this methodological approach are discussed in detail in this article and its improvement is proposed.

Thus, in Ukraine, it is extremely urgent to develop new approaches to assess the degree of danger at the regional and local levels in order to make scientifically-based management decisions on the priority of implementing environmental protection measures and preventive measures for civil protection of the population.

The aim of the presented research is to improve methods for determining the risk of air pollution on public health. To achieve this goal, the following tasks are set:

– identification of regions of Ukraine with a high level of risk of air pollution and the risk of technogenic emergencies;

– health risk assessment in industrial regions of Ukraine;

– identification of potential risk to public health due to air pollution in industrial regions of Ukraine;

– determination of the effect of pollutants emissions of blast furnace plant of "Azovstal" metallurgical combinat on public health.

The new method presented in this work to determine the level of danger of air pollution allows us to spot the regions of Ukraine that are in the worst condition in terms of air pollution, emergencies, human pressure, and the likelihood of an increase in the incidence of the population. When making scientifically-based management decisions in the field of technological environmental safety, it will allow industrial enterprises to fulfill the requirements of the Law of Ukraine "On Environmental Impact Assessment".

3. Methods and Methodology. Determination of the level of air pollution danger while maintaining existing trends in anthropogenic load and the possibility of industrial emergencies

3.1 Identification of Ukrainian regions with a high risk of air pollution and the risk of industrial emergencies

The need to determine ecological risk as a macroecological indicator for the regions of Ukraine is specified by the state environmental policy according to the regional principle. In particular, the authors introduced the definition of a macro-environmental indicator as a component of life quality assessment (Рибалова О.В. та ін., 2021).

Ecological risk (P^c_i) as probability of ecosystem resilience depends on the current state of ecosystem components (K^c_i) and the impact of present or potential anthropogenic load (H^c_i) and can be expressed by

function (Васенко О.Г. та ін., 2015):

$$P_i^c = f\left(K_i^c, H_i^c\right), \quad (1)$$

where

K^c_i – current state of i-component of the environment;

H^c_i– current level of anthropogenic pressure on i- component of the environment.

It is proposed to determine the ecological risk of deterioration of air quality by the formula (Васенко О.Г. та ін., 2015).:

$$P_A = f(A_b\langle b = \overline{1, N_A}\rangle, H_{Ak}\langle k = \overline{1, N_{HA}}\rangle), \quad (2)$$

where

A_b – complex assessment of the present state of the air quality by N_A numbers and b- indicators;

H_{Ak}– an integral assessment of the current level of anthropogenic load from the effects of negative factors on air for N_{Ha} numbers and k - indicators.

The characteristics of air pollution in the regions of Ukraine are estimated by the integral indicator of air pollution index value IPV, because it is the most widespread and using in the state monitoring system.

In order to determine the integral indicator of air condition, it is necessary to interpolate the indicators of air quality (A_b) and the value of the integral status indicator and the air pollution index value (IPV) according to the table 1.

To calculate the anthropogenic load on the state of the air quality, official data on the total amount of pollutants emitted from stationary and mobile sources of pollution were analyzed. The following rank scale was used to determine the level of danger of anthropogenic pressure on natural ecosystems (table 2).

Table 1

Classification of the quality state of air by the values of the state integral indicator of the quality state of air (A_b) and air pollution index value (IPV) (Васенко О.Г. та ін., 2015)

Air quality class	*1 - good*	*2 - fair*	*3 - moderate*	*4 - poor*	*5 - heavy*
Value of the state integral indicator of the quality state of air (A_b)	0 - 0,19	0,2 - 0,39	0,4 - 0,59	0,6 - 0,79	0,8 -1,0
Air pollution index value (IPV)	0 - 5	5,1 - 8	8,1-13	13,1 - 18	18,1 -30

Table 2

Characteristics of anthropogenic pressure on natural ecosystems (Васенко О.Г. та ін., 2015)

Value of the anthropogenic pressure indicator	*Danger level of anthropogenic pressure on natural ecosystems*
0,01 - 0,40	Minor pressure
0,41 – 0,80	Increased pressure
0,81 – 1,00	Intense pressure
1,01 – 1,80	High pressure
> 1,80	Dangerous pressure

Special danger with possible grave consequences and the number of victims are accidents with the release of hazardous chemicals into the environment. Most enterprises in all industries work on technically outdated equipment, consuming large quantities of natural resources, including mineral resources. Production is accompanied by the formation of a large amount of waste and by-products, are not disposed of, stored in dumps. On average, only about 40% of the recyclable chemical raw material is converted into finished products. The most common hazardous chemicals at the chemical industry are ammonia, chlorine, nitrogen dioxide, acrylonitrile, sulfuric anhydride, concentrated nitric and sulfuric acids, methanol, benzene, sodium hydroxide, formalin, etc.

It should be noted that the state of the air quality is greatly influenced by emergencies associated with accidents at chemically hazardous facilities, which result in sudden emissions of hazardous chemical substances (HCS) into the environment. Therefore, it is necessary to consider the chemical hazard indicator (X_{An}) in determination of the ecological risk of deterioration of state air quality:

$$P_A = f(A_b\left\langle b = \overline{1, N_A}\right\rangle, H_{Ak}\left\langle k = \overline{1, N_{HA}}\right\rangle), X_{An}\left\langle n = \overline{1, N_{XA}}\right\rangle\Big\rangle, \quad (3)$$

where

X_{An} – an integral indicator of the influence of chemical hazard factors on state of air quality for N_{XA} numbers of n indicators.

Ecological risk characterization by value is given in table 3.

The determination of the state of air quality and the anthropogenic load indicator in the regions

of Ukraine is based on official monitoring data and information, are given in the environmental passports of the regions of Ukraine, regional reports on the state of the environment, National reports on the state of the environment, information and analytical reviews "State of the environment in Ukraine". For determination of the generalized indicator of the influence of chemical hazard factors on the state of air, the information of the National Report on the State of Technogenic and Natural Safety in Ukraine were used.

Based on these data, the ecological risk of deterioration of the state of air quality of Ukraine is determined taking into account the degree of chemical hazard (fig. 1).

According to calculations of the ecological risk

Table 3

Characteristics of ecological risk (Васенко О.Г. та ін., 2015)

Value of the ecological risk indicator	*Qualitative assessment of the degree of ecological risk*
0,01–0,19	Low risk
0,20–0,39	Increased risk
0,40–0,59	Significant risk
0,60–0,79	High risk
0,80–1,00	Dangerous risk

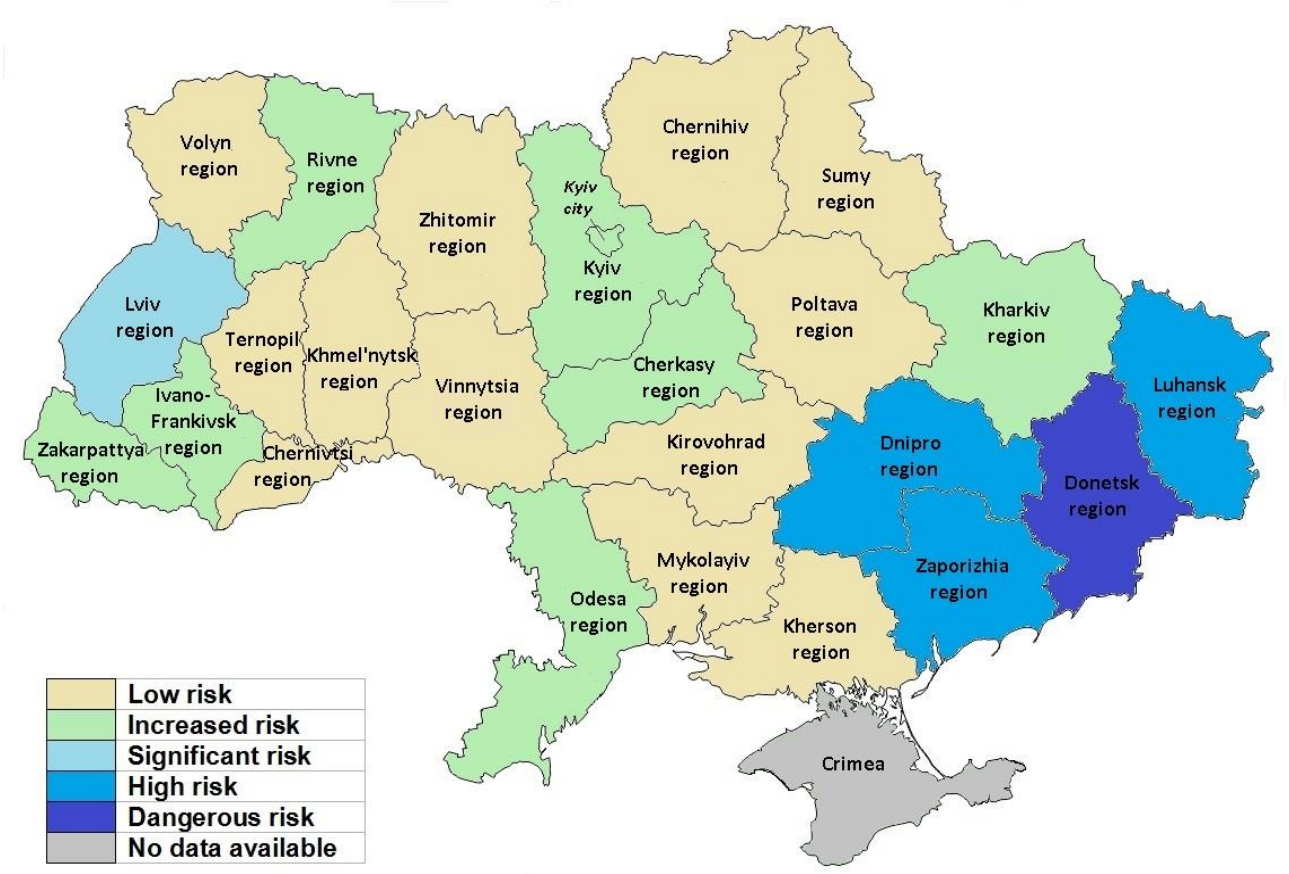

Fig. 1. Ecological risk of deterioration of air in the regions of Ukraine, taking into account the degree of chemical hazard

of deterioration of atmospheric air in Ukraine, taking into account the chemical hazard indicator (fig. 1), the most dangerous state of atmospheric air is observed in Donetsk (5 class), Dnepropetrovsk, Lugansk region and Zaporizhzhya region (4 class).

More than 11.0 million people (about 26% of the country's population) live in the zones of possible chemical contamination. The largest number of chemically hazardous facilities is concentrated in the industrial regions of Ukraine, namely in the Donetsk region - 159, Dnipropetrovsk region - 112, Lugansk region – 86. Most of these facilities constitute an ecological hazard to the environment and public health, pose a threat of emergencies, and individual facilities are potentially dangerous even to neighboring states and constitute a transnational threat.

3.2 Method of estimating the risk to public health depending on air quality

In the most countries of the world it is considered that the risk to the public health is the main

indicator of danger. Ukraine has guidelines for assessing the risk to public health from air pollution (Методичні рекомендації, 2007). In the article (Rybalova O. et al., 2022). the methodology for a complex assessment of the risk to public health at environmental pollution was improved.

Health risk assessment is carried out separately for carcinogenic and non-carcinogenic pollutants. For the assessment of the carcinogenic risk, risk indicators are calculated for each pollutant (Методичні рекомендації, 2007):

$$CR = SF \times LADI, \quad (4)$$

where

CR – the probability of getting cancer, immeasurable value (usually expressed in units 1:1000000);

SF – probability of getting cancer if a single dose was taken LADI, 1/mg/ (kg· twenty-four hours).

LADI – average lifetime daily dose, mg/(kg-twenty-four hours), which is calculated by the formula (Методичні рекомендації, 2007):

$$LADDI = \frac{Ca \times Tout \times Vout \times EF \times ED}{BW \times AT \times 365}, \quad (5)$$

where

LADDI – average daily dose of the substance, mg/kg- twenty-four hours;

Ca – concentration of substances in the air, mg/m^3;

Tout – time spent outdoors, hour/ twenty-four hours;

Vout – rate of breathing outside the room, m^3/year;

EF – frequency of exposure, days/year;

ED – duration of exposure, years;

BW – body weight, kg;

AT – exposure averaging period, years.

365 – number of days per year.

Individual and population carcinogenic risks characterize the upper limit of a possible carcinogenic risk during the period corresponding to the average human life expectancy (70 years). Value of carcinogenic risks mainly reflects the long-term tendency for a change in the oncological background that has formed in the corresponding territory. Low level of carcinogenic risk is considered at its values $10^{-4} – 10^{-6}$.

The risk of developing non-carcinogenic effects for individual substances is based on the calculation of the hazard coefficient by the following formula (Методичні рекомендації, 2007):

$$HQ = \frac{AD}{RfD} \quad \text{or} \quad HQ = \frac{AC}{RfC}, \quad (6)$$

where

HQ – coefficient of hazard, immeasurable value;

AD – average dose, mg/kg;

AC – average concentration, mg/m^3;

Rf D – reference (safe) dose, mg/kg;

RfC – reference (safe) concentration, mg/m^3.

The risk characterization of the development of non-carcinogenic effects with combined and complex exposure to chemical compounds is based on the calculation of the hazard index (HI).

The hazard index for conditions of simultaneous using several substances in the same way (for example, inhalation or oral) is calculated by the formula (Методичні рекомендації, 2007):

$$HI = \sum HQ_i, \quad (7)$$

where HQ_i – hazard factor for i- individual pollutants.

In works (Васенко О.Г. та ін., 2015), the following gradation of the boundaries of the development of non-carcinogenic effects by the magnitude of the hazard coefficient is presented: extremely high (> 10), high (5-10), medium (1-5), low (0.1-1.0), minimal (less than 0.1).

3.3 Method of estimating the potential risk to public health depending on air quality

When identifying areas of environmental danger, methods are used to assess the potential risk to public health, the advantage of which is that they are based on the domestic hygienic approach (compliance with the maximum allowable concentration (MPC) ensures no adverse health effects, and its excess can cause probability (risk) of increasing the incidence of the populatiWon), which allows to divide the levels of pollution into several stages - from acceptable (or acceptable) to extremely dangerous (Васенко О.Г. та ін., 2015, Киселев А.В., Фридман К.Б., 1997).

The method of assessing the potential risk to public health allows you to adequately integrate pollutants, because it is a probabilistic characteristic of the occurrence of reflex reactions of the body and other harmful effects (Васенко О.Г. та ін., 2015).

The potential risk to public health from chronic exposure to air pollution is determined by the formula (Киселев А.В., Фридман К.Б., 1997):

$$R = 1 - \exp(\ln(0.84) \times (C / MPC)^b / Kz), \quad (8)$$

where

C – concentration of the pollutant, mg/m^3;

MPC – maximum permissible concentration of the pollutant, mg/m^3;

Kz – coefficient, which is determined by table 4;

b – coefficient that allows to evaluate the isoeffective effects of impurities of different hazard classes in accordance with table 4.

When interpreting the obtained values of the potential risk to public health use the following ranking scale (table 5).

Assessing the potential risk to public health also allows you to rank the risks of individual pollutants

Table 4

The values of the coefficients Kz and b for substances of different hazard classes (Киселев А.В., Фридман К.Б., 1997)

Hazard class of pollutants	Coefficient Kz	Coefficient b
1	7,5	2,35
2	6,0	1,28
3	4,5	1,0
4	3,0	0,87

Table 5

Dependence of the weight of the effects on the magnitude of the potential risk to public health (Rybalova O. et al., 2018)

Risk	**Grade**	**Risk characteristics**
<0,1	1	insignificant impact on public health
0,1 – 0,19	2	weak impact on public health
0,2 – 0,59	3	significant impact on public health
0,6 – 0,89	4	great impact on public health
0,9 – 1,0	5	very large impact on public health

in order to determine the cause of pollution based on the identification of the most dangerous sources of anthropogenic impact on the environment.

4. Results

4.1 Results of risk assessment for public health due to air pollution in industrialized regions of Ukraine

Calculations of carcinogenic risks to public health in the current state of air pollution in all regions of Ukraine correspond to the low level, as their values fluctuate from 10^{-5} till 10^{-6}.

The calculation of the hazard index of an increase in the incidence of the population showed a high level of danger in industrial regions (fig. 2).

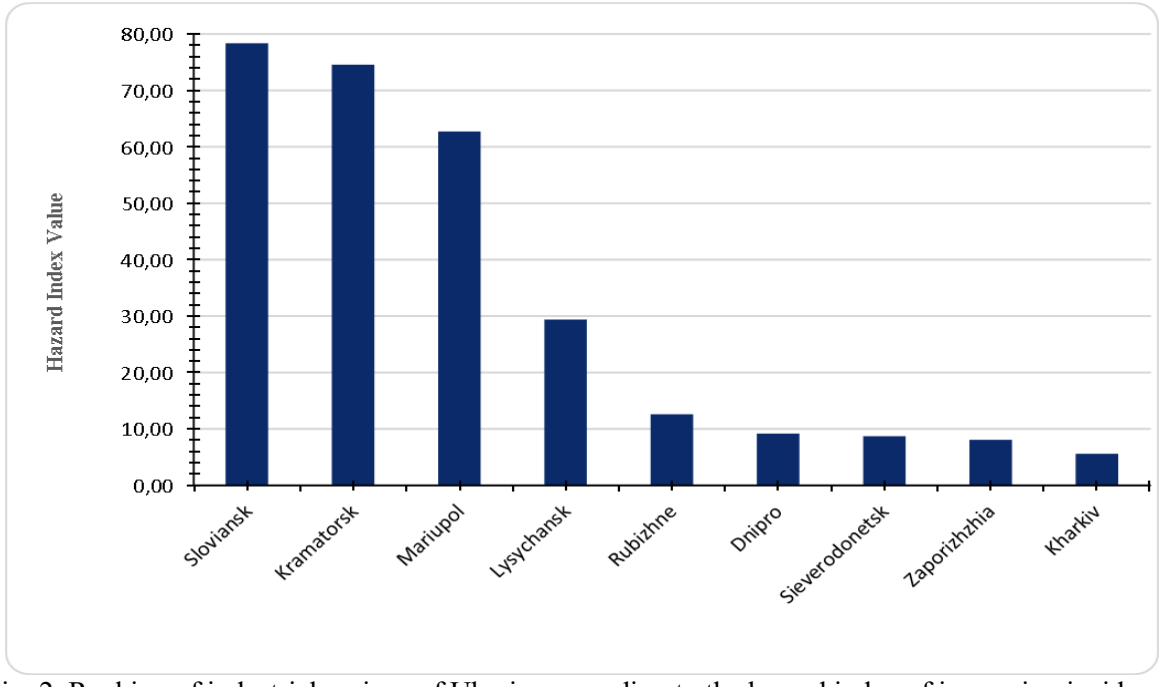

Fig. 2. Ranking of industrial regions of Ukraine according to the hazard index of increasing incidence of the population in the current state of air pollution

Based on the monitoring data on the state of air in the settlements of Ukraine, the carcinogenic risk and the hazard index for non-cancer diseases for adults and children are calculated. The population in the Donetsk region is in the most dangerous condition: the hazard index value corresponds to hazard class 5 (extremely high hazard level). The level of air pollution in Lugansk, Dnipropetrovsk and Kharkiv regions corresponds to 4 class (high hazard level).

The assessment of the potential risk to public health from air pollution in Luhansk region showed that the value of the risk corresponds to hazard classes 2 and 3 (table 6).

Table 6

Potential risk to public health from air pollution in Luhansk region

Name of the city	The value of potential risk	Grade	Risk characteristics
Lysychansk	0,36	3	significant impact on public health
Severodonetsk	0,19	2	weak impact on public health
Rubizhne	0,39	3	significant impact on public health

Calculations have shown that the greatest potential risk to public health from air pollution in Rubizhne.

An assessment of the potential risk to public health from air pollution in the Donetsk region has shown that the level of air pollution is extremely dangerous (Grade 5).

The ranking of the cities of Donetsk region by the value of the potential risk to public health from air pollution showed the most dangerous level of pollution in the city of Slavyansk.

The level of air pollution in the city of Zaporizhzhya and the city of Dnipro according to the assessment of the potential risk to public health corresponds to the 3rd grade of danger (significant impact on public health). The assessment of the potential risk to public health from air pollution in the city of Kharkiv showed compliance with hazard grade 2 (weak impact on public health).

4.2 Determination of the effect of pollutant emissions from the blast furnace shop of the PJSC "Azovstal Iron and Steel Works"on public health

The main air pollutants in Ukraine are energy and metallurgy enterprises (55% and 22% of all pollution from stationary sources). The powerful environmental pollutant is also chemical industry, which emits sulfuric anhydride, hydrocarbons, nitrogen oxides and other harmful substances into the air. The largest number of chemically hazardous facilities is located in the eastern regions of the country, namely in Donetsk, Dnipropetrovsk, Lugansk and Kharkiv regions.

The industrial center of Ukraine is concentrated in the Donetsk region, which carries a large load on the environment by such industries as coal, metallurgy, energy, coke-chemical engineering and others. Therefore, pollution of the atmosphere in the Donetsk region and in the city of Mariupol with harmful substances has a significant impact on the health of the population and natural ecosystems.

Results of the calculations of the carcinogenic risk assessment on the health of the population of Mariupol at the current level of air pollution are showed that there is a high risk - it is not acceptable for the working environment and the population as for children, as for adults. It is necessary to implement and take measures to eliminate or reduce the risk. For adults and children, the highest risk is high levels of air pollution by benzopyrene. (fig. 3).

The assessment of non-carcinogenic risks to the

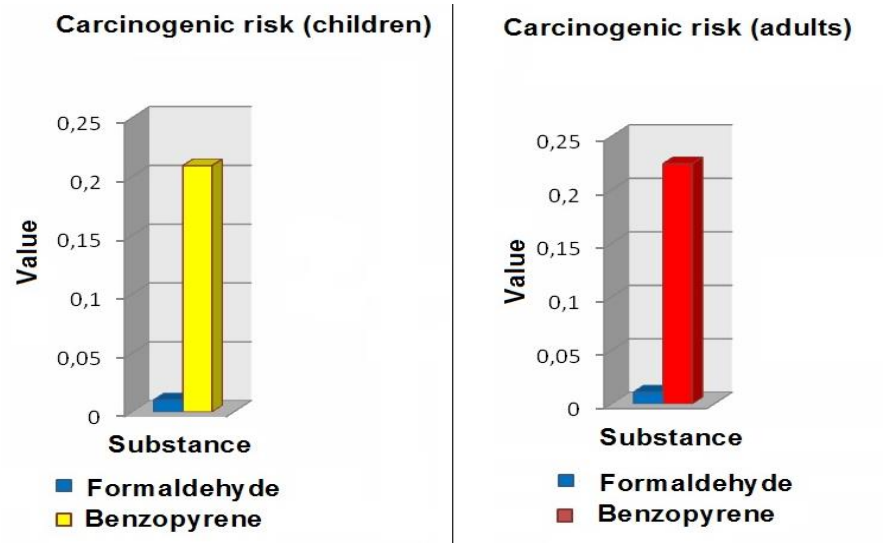

Fig. 3. Carcinogenic risk for children and adults in the city of Mariupol (Donetsk region)

public health at the current level of air pollution is showed that the risk is extremely high - massive complaints and the occurrence of chronic diseases.

Hazard index calculations show that the hazard level is extremely high, which creates the probability of increasing the morbidity of the population.

Main contribution to the general air pollution of the city of Mariupol is made by the enterprises of ferrous metallurgy – PJSC "Azovstal Iron and Steel Works" and PJSC “Ilyich Iron and Steel Works". Their emissions, according to Ministry of ecology and natural resources, constitute about 98% of the

citywide.

PJSC "Azovstal Iron and Steel Works" is a part of metallurgical division (Metinvest group) and one of the largest world - known metallurgical companies in Ukraine (city of Mariupol). Production facilities of the enterprise allow producing 5.7 million tons of iron per year, 6.2 million tons of steel and 4.7 million tons of finished rolled products per year. Currently, enterprise is the only Ukrainian manufacturer of high-quality rolled products with the thickness of 6-200 mm and width of 1500-3200 mm for shipbuilding, power engineering and special machine building, bridge construction, large diameter pipe manufacturing for arctic main gas and oil pipelines, offshore structures. PJSC "Azovstal Iron and Steel Works" uses five main workshops for production, namely: sinter factory, blast-furnace shop, converter shop, thick-sheet shop.

The most ecologically hazardous is the blast furnace shop of metallurgical production. Therefore, the effect of pollutant emissions into the air of a blast furnace shop of PJSC "Azovstal Iron and Steel Works" on the health of population were considered in more detail at the article.

The blast furnace shop of PJSC "Azovstal Iron and Steel Works" produces three types of pig iron:

- 30% phosphorous (phosphorus content up to 1.5%) for the open-hearth shop;
- 69,5 % low carbon (manganese content up to 0.17%) for the converter shop;
- 0,5 % synthetic cast iron for foundry.

The main sources of atmospheric emissions in the steel industry are sinter production, iron and steel production. A large amount of pollutants is emitted into the atmospheric air: carbon oxides, sulfur, nitrogen, oil vapors, polydispersity dust, benzene, phenol, formaldehyde, methanol, heavy metals, and ammonia. The main air pollutants are given in table 7.

Emissions of pollutants lead not only to a critical state of air and nature in the city, but also to the large

Table 7

The main air pollutants of PJSC "Azovstal Iron and Steel Works"

Title of the pollutant	Emissions		
	Total emissions, t/year	Before the total emissions of the facility, %	Before the total emissions (settlement), %
Solids	11191.265	7.73	2.93
CO	121249.068	83.73	31.71
NO_X	6408.391	4.43	1.68
SO_2	4877.254	3.37	1.28

number of diseases among the population of the region of the cardiovascular, respiratory and reproductive systems and the death of living organisms.

The main sources of air pollution from emissions from a metallurgical enterprise include blast furnace production of pig iron. Therefore, calculating the effect of pollutant emissions into the air from the blast furnace is necessary.

Calculations of the hazard index for the population of the city of Mariupol from on the emissions of the blast furnace into the air showed a high level of danger (table 8.)

Assessment of non-carcinogenic risks to public health at the current level of air pollution shows that the risk is extremely high - massive complaints and the occurrence of chronic diseases. In accordance with the methodology for assessing the risk to public health, the probability of increasing the incidence rate for individual organs and systems of the human body is determined in accordance with the value of the hazard coefficient of an individual pollutant (fig. 4).

Calculations are shows that there is a high level of danger of an increase in the incidence of the respiratory, blood and immune system for the population of the city of Mariupol.

The blast furnace production is one of the main branches in the steel industry, which pollutes the environment. The production of pig iron is formed big amount of gas emissions and waste. In order to protect the environment, the implementation of measures aimed at: 1) eliminate or reduce emissions to maximum permissible standards; 2) neutralization of harmful factors of pollution. Among the highest priorities, it is necessary to name the full or partial conversion of production, accelerated restoration of production potential, the implementation of advanced technologies, and the development of environmentally friendly industries. Complete and efficient disposal of waste from all industries is possible and necessary based on the implementation of activation tools with a significant increasing in their technological properties.

One of the main levers for solving the problems of air protection, in terms of approaching international air quality standards and eliminating the contradictions between economic growths and increasing

Table 8

Assessment of the hazard index for the population in the city of Mariupol depending on the emissions of pollutants from the blast furnace shop into the air

Pollutants	Concentration, mg/m^3	Reference concentration, RfC, mg/m^3	Hazard factor, HQ
Dust	0.7	0.1	7
Sulfuric anhydride	0.33	0.05	6.6
Nitrogen oxides	0.1	0.06	1.67
Carbon monoxide	9	3	3
Hydrogen sulfide	0.01	0.1	0.1
Total hazard index, HI			18.37

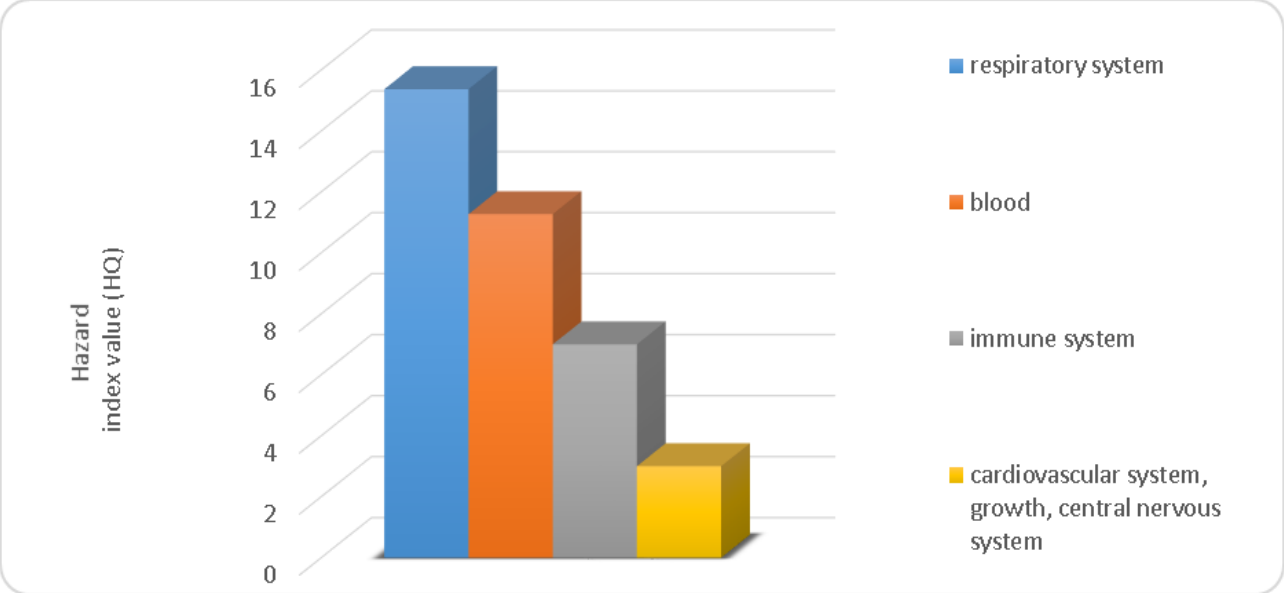

Fig. 4. Probability of an increase in the morbidity of the population of Mariupol from modern air pollution from emissions from the blast furnace of PJSC "Azovstal Iron and Steel Works"

anthropogenic load, is the implementation of a new industrial emissions control system. Thus, the ecological situation in the area of pig iron production can be improved by replacing the treatment facilities with new, more productive and modernized ones; reducing the formation of scrap and slag and the development of measures for their disposal and recovery.

5. Discussion

Analysis of the dynamics and state of natural and technological safety in Ukraine showed that in general the number of emergencies has a tendency to decrease over the past decade. The big number of technogenic emergencies arose in the Donetsk, Dnepropetrovsk and Lugansk regions. This is due to the deterioration and obsolescence of technological equipment of industrial enterprises, especially in ecologically and chemically hazardous facilities. In the Donetsk and Lugansk regions, the situation is complicated by military operations. The peculiarity of the Donetsk and Lugansk regions is the presence of a large number of objects of increased technogenic danger, which because of hostilities are at risk of explosions, damage and other emergencies, which leads to chemical pollution of soil, air, surface and groundwater.

The application of a new method of determining the risk of deterioration of atmospheric air depending on the current state of the atmosphere, anthropogenic load, taking into account the degree of man-made chemical danger at the state level has shown its effectiveness for fair distribution of financial resources for the introduction of advanced technologies and environmental measures.

The main air pollutants in Ukraine are energy and metallurgical enterprises (55% and 22% of all pollutants from stationary sources). A powerful pollutant of the environment is also the chemical industry, whose facilities emit sulfur dioxide, hydrocarbons, nitrogen oxides and other harmful substances. The largest number of chemically dangerous objects

is located in the eastern regions of the country, namely in Donetsk, Dnipropetrovsk, Luhansk and Kharkiv regions.

Modern methodological approaches to risk assessment for public health were analyzed and the authors came to conclusion that due to the heterogeneity of approaches there is currently no consensus on methods of solving problems related to risk assessment (Mathes T. et al, 2017). A possible explanation for this may be that the methods are insufficiently developed, and the advantages and disadvantages of a particular method in relation to the research question are still insufficiently evaluated (Mathes T. et al, 2017).

A comparison of methodological approaches to assessing the risk to public health revealed several shortcomings of the EPA methodology:

1) pollution indicators of the Ukrainian and American monitoring systems do not match;

2) calculation of the hazard index is based on a simple summation of the multiplicity of exceeding the reference doses without taking into account the hazard class;

3) the concept of non-threshold risk (ie any substance in any concentration affects human health) leads to overestimation of risk values;

4) for each pollutant indicate specific diseases that may be increased compared to the background disease, but sometimes these are very dubious conclusions about the disease;

5) the method of assessing the potential risk to public health is based on the fact that if the pollutants exceed the relevant maximum concentration limits, then there is a likelihood of adverse effects or increased morbidity and do not indicate specific diseases;

6) assessment of the potential risk to public health is based on the domestic system of maximum permissible concentrations (MPC) and takes into account the hazard class of the substance

We propose to use a combined approach to determine the risk to public health due to air pollution:

1) carcinogenic risk is determined according to the methodological approach of the EPA, which is contained in the methodological recommendations 2.2.12-142-2007 "Assessment of the risk to public health from air pollution".

2) for non-carcinogenic pollutants to determine the potential risk to public health according to the method presented in section 3.3 of this work.

The next step in determining the risk to public health is risk management (Keim M. 2018). where it was noted that risk assessment is a key component of health interventions aimed at preventing or reducing adverse health effects. Health risk assessments are widely used to guide health programs, as well as cross-sectoral environmental impact studies and development decisions. Analytical risk assessment is a well-validated tool that is regularly used among certain subgroups of public health, including those that assess chemical, radiological and microbiological risks.

One of the main levers for solving the problems of air protection, in terms of approaching international air quality standards and eliminating contradictions between economic growth and increasing man-made load, is the introduction of a new system for regulating industrial emissions. Thus, it is possible to improve the ecological situation, protect human health and ensure the comfort of living by introducing advanced technologies into industrial production, replacing treatment plants with new, more productive and modernized ones; reducing waste generation and developing measures for their utilization and recovery.

6. Conclusions

The new method of determining the level of danger of air pollution allows to identify the regions of Ukraine that are in the worst condition in terms of air pollution, emergencies, anthropogenic pressure, the likelihood of increasing morbidity to direct financial resources to implement environmental measures and prevention. Emergencies, which is a very important task in making scientifically sound management decisions in the field of man-made environmental safety.

Calculations of the ecological risk of deterioration of the atmospheric air of Ukraine taking into account the indicator of chemical danger showed the most dangerous state of the atmospheric air observed in Donetsk, Dnipropetrovsk, Luhansk regions (5th grade) and in Zaporizhzhya region (4th grade).

The industrial center of Ukraine is concentrated in the Donetsk region, which carries a large load on the environment by such industries as coal, metallurgy, energy, coke-chemical engineering and others. Air pollution in the Donetsk region and in the city of Mariupol with harmful substances has a significant impact on public health and natural ecosystems. Therefore, it is very important to assess the risk for the population of the city due to air pollution. Results of calculations of carcinogenic risk assessment for the population of Mariupol at the present level of air pollution showed that the risk is very high.

A comparison of methodological approaches to assessing the risk to public health from air pollution has shown the need to use a combined approach to determine carcinogenic and non-carcinogenic risk. Applying the proposed combined approach to assessing the risk to public health will determine the likelihood of increasing morbidity at the regional and local levels, the possibility of industrial enterprises or the introduction of advanced technological processes to improve air quality and protect the public from pollutant emissions.

The assessment of non-carcinogenic risks for public health at the current level of air pollution showed that there is a very high risk of chronic diseases, especially respiratory and cardiovascular systems, the central nervous system. The main sources of pollution in the city of Mariupol are metallurgical plants: PJSC "Azovstal Iron and Steel Works" and PJSC “Ilyich Iron and Steel Works"and vehicles, which are growing rapidly year-by-year.

The enterprises of the metallurgical industry, which are the largest air pollutants, should immediately implement air protection measures in order to reduce the risk to public health.

The results of the air quality assessment in Donetsk region and the city of Mariupol and its impact on public health are showed that the region’s environmental strategy financial resources should be allocated to the implementation of environmental protection measures and for the technological modernizа-tion of industrial enterprises in order to reduce the anthropogenic load on the environment.

Nowadays, Ukraine has experienced an economic crisis, the issue of the priority of financing environmental protection is very important. The presented approach for determation the level of environmental hazard using methods for assessing the risk to public health makes it possible to determine the feasibility and priority of implementing environmental and sanitary-hygienic measures. The hierarchical methodological approach proposed in the work for determination the environmental hazard of air pollution should be used in the development of environmental policies for the implementation of environmental measures in order to improve the state of the environment.

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Оцінка ризику для здоров'я населення від забруднення повітря в промислових регіонах України

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Основною метою проведення досліджень є підвищення ефективності прийняття управлінських рішень в галузі охорони навколишнього природного середовища за рахунок застосування методів оцінки ризику для здоров'я населення при сучасному рівні забруднення атмосферного повітря. В роботі представлено ієрархічний методичний підхід до визначення рівня небезпеки забруднення атмосферного повітря на державному, регіональному і місцевому рівнях. В статті представлена нова методика визначення рівня небезпеки забруднення атмосферного повітря при збереженні існуючих тенденцій антропогенного навантаження та можливості виникнення надзвичайних ситуацій техногенного характеру. На стан атмосферного повітря великий вплив мають надзвичайні ситуації, що пов'язані з аваріями на хімічно небезпечних об'єктах, у результаті яких відбувається залпові викиди небезпечних хімічних речовин в навколишнє природне середовище. При визначенні екологічного ризику погіршення стану атмосферного повітря враховано показник хімічної небезпеки. На території Сходу України налічується найбільша кількість потенційно небезпечних підприємств. Визначення ризику як макроекологічного показника за новою методикою показала високий рівень небезпеки забруднення атмосферного повітря в індустріально розвинутих регіонах України. Оцінка ризику для здоров'я населення внаслідок забруднення атмосферного повітря м. Маріуполь показала надзвичайно високий рівень небезпеки. Для регіонів України з високим рівнем екологічної та хімічної небезпеки дана оцінка ризику для здоров'я населення при сучасному якісному стані атмосферного повітря двома різними методами. Показано недоліки методичного підходу Агентства з охорони навколишнього середовища США (EPA US), що широко використовується у багатьох країнах світу. Аналіз методичних підходів до оцінювання ризику для здоров'я населення показав перспективність застосування методики оцінки потенційного ризику при визначенні рівня екологічної небезпеки промислових підприємств. Запропоновано удосконалення методики оцінки ризику для здоров'я населення внаслідок забруднення атмосферного повітря, що представляє наукову новизну роботи. В теперішній час, коли Україна зазнала впливу військових дій та економічної кризи, дуже важливим є питання щодо пріоритетності фінансування природоохоронних заходів. Застосування запропонованого методичного підходу дасть змогу науково обґрунтовано визначити регіони з підвищеним рівнем небезпеки для здоров'я населення і мінімізувати фінансові ресурси на покращення стану атмосферного повітря, що є актуальним і має практичну значимість.

Ключові слова*: атмосферне повітря, надзвичайні ситуації, хімічна небезпека, ризик, здоров'я населення, викиди забруднюючих речовин, промислові регіони України.*

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