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Risk management algorithm for ensuring the sanitary safety of the population in the area of the oil refinery

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Abstract

The article reveals the main features and characteristics of the algorithm of actions to ensure environmental safety of the population in the areas of oil refineries based on the mechanism of health risk assessment at all stages of the life cycle of environmentally hazardous production facilities. Methodologically, the algorithm implements the provisions of existing standards, regulatory documents and recommendations on health risk assessment of the population and is a sequence of procedures for making informed decisions on ensuring that health risk to the population exposed to potential negative environmental impacts meets the regulatory level. Application of the algorithm ensures compliance with the regulatory level of environmental impacts on the border of the sanitary protection zone of oil refineries and adjacent residential areas.

A special emphasis is made on the stages of design and operation of environmentally hazardous objects, when the level of created health risks is especially sensitive to the results of decisions made. Timely identification of hazards and assessment of health risks at the design stage helps to choose the location of environmentally hazardous facilities, considering created risks in specific industrial and urban conditions. At the operation stage, the areas with highest risk levels of the sanitary protection zone boundary and the industrial site are identified, as well as priority production facilities and chemical toxicants (in terms of created risks). This gives a reason for adjusting the programs of industrial and environmental control, for specifying the priority of investment programs and plans of environmental protection measures. In practical terms the specific features of actions in conditions of high risks are defined to ensure the health risk meets the regulatory level in functioning of environmentally hazardous oil refining object, avoiding significant financial environmental costs as a result of making ecologically insufficiently justified planning and technological decisions at the design stage. The algorithm is universal, because it can be used for the existing production facilities and new construction projects, regardless of industry specifics.

Keywords: risk management, health risk assessment from chemical air pollution, normative level of health risk, the most dangerous areas of the sanitary protection zone boundary, priority risk creating facilities, priority risk creating chemical toxicants.

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确保炼油厂附近居人群的环境安全的风险管理算法

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摘要
文章揭示了为确保炼油厂所在地区居人群的环境安全而采取的行动算法的主要特点和特殊性，其依据是对环境有害的生产设施的生命周期的各个阶段的健康风险评估机制。在方法上，该算法执行了现有的公共卫生风险评估标准、法规和指南的规定。该算法是一套连续的程序，用于作出明智的决定，以确保暴露于潜在不利环境影响的人群的健康有一个规范的残余风险指标。该算法的应用确保了炼油厂和邻近居群民区的卫生防护区边界符合环境影响的监管水平。
特别强调的是环境危险设施的设计和运营阶段，此时，所带来的健康风险水平对决策的结果特别敏感。在设计阶段及时评估健康风险，可以根据具体工业和城市环境中的危险性来确定环境危险设施的位置。在经营阶段，可确定卫生防护区边界和工业场地的最危险区域，以及优先（就产生的风险大小而言）的生产装置和化学毒物。这为调整工业控制和工业环境控制方案，以及明确环境保护措施的投资方案和计划的优先次序提供了依据。制定了在高风险环境中实际行事的具体内容，为确保环境危险的炼油生产设施运营期间对公众健康的残余风险达到监管水平。在设计阶段提供无害环境规划和技术解决方案的结果是将避免巨大的环境财政成本。该算法是通用的。它既可用于现有的生产基地，也可用于新建筑工地，不受行业限制。
关键词：风险管理，化学空气污染的健康风险评估，残余健康风险规范性水平，卫生防护区边境最危险的地区，有风险的优先装置，有风险的优先化学毒物。

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Introduction

In the modern world the creation of wealth is increasingly accompanied by the social production of risks [Beck, 2000], and billions of people, thinking about what is happening, experience confusion and anxiety, as past habits and traditions of managing are losing effectiveness before our eyes. A significant increase in recent years in the role of anthropogenic and natural risks [The global risks.., 2018; 2021; 2022] corrects the very basic understanding of sustainable development[1], which is increasingly seen as the ability of individuals, communities and geosystems[2] to survive; Moreover, the term itself is increasingly being supplemented, and even replaced by the concept of resilience, understood as the preservation of viability and the reduction of vulnerability in a risky external environment.

Such a vision of sustainability is especially relevant when it comes to the population of regions with a highly developed industry, especially mining, oil refining, petrochemical, metallurgical, mineral fertiliser production and heat and power generation industries. The burden of disease attributable to air pollution is now on par with other major global health risks such as tobacco smoking. According to WHO[3], every year exposure to polluted air leads to 7 million premature deaths and a catastrophic reduction in healthy life years. Up to 30% of deaths from the dominant non-communicable diseases (stroke, lung cancer and chronic obstructive pulmonary disease) and 25% of deaths from heart attack are associated with air pollution, with adverse health effects most pronounced among women, children, the elderly and the poor [Rakitsky et al. ., 2019]. Back in 2013, IARC[4] classified outdoor air pollution as carcinogenic to humans (Group 1). An increasing risk of developing lung cancer with increasing air pollution has been confirmed[5].

The size of the negative consequences and damage to health from the impact of industrial emissions on vital organs, at first glance, is incomparable with the situations of major man-made accidents and disasters. Nevertheless, the

[1] On October 20, 1987, at the Plenary session of the UN General Assembly, the Brundtland Commission adopted a resolution defining the basic principle of sustainable development: “This is development that meets the needs of the present, but does not jeopardize the ability of future generations to meet their own needs” [Our Common. ., 1989].
[2] Geosystem - a territorial entity that is formed in close relationship and interaction of nature, population and economy, the relative integrity of which is determined by direct, reverse and transformed links developing between the subsystems of the geosystem.
[3] https://www.who.int/europe/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution.
[4] IIARC stands for International Agency for Research on Cancer and is part of the United Nations World Health Organisation.
[5] https://www.iarc.who.int/wp-content/uploads/2020/12/pr292_E.pdf.

available environmental and economic calculations indicate a fairly high, almost comparable level [Brody, Golub, 2014; Golub, 2021].

The rapid development of the oil industry dates back to the mid-1950s, when, according to J. Simon, oil became the most important source of energy in the world [Simon, 2005]. Oil refineries, many of which have historically been located near residential areas, are well-known sources of a wide range of air pollutants. The main recognised air pollutants include: sulfur oxides, nitrogen oxides, carbon monoxide and dioxide, volatile organic compounds (VOCs), volatile PAHs and various metals, especially arsenic, cadmium and mercury [Revich et al., 2004; Fomenko et al., 2010; Valeev et al., 2014; Kampeerawipakorn et al., 2017; Domingo et al., 2020; Marques et al., 2020]. According to IARC[6], some of these substances, such as arsenic, cadmium, and some VOCs and PAHs, are carcinogens; plant workers and people living near refineries are at increased risk of developing various types of cancer [Onyije et al., 2021].

According to Russian legislation, compliance with regulatory environmental requirements is established as one of the mandatory conditions for the operation of an industrial enterprise to exercise the rights of citizens to a favourable environment, reliable information about its condition and compensation for damage caused to health or property by an environmental offense (Article 42 of the Constitution of the Russian Federation). Particularly stringent requirements are imposed on environmentally hazardous facilities[7], which include oil refineries. During the commissioning of new and (or) reconstruction of existing facilities, as well as during their operation, along with ensuring that technological emission standards and (or) maximum allowable emissions[8] are not exceeded, responsibility is established for ensuring an acceptable level of health risk at the border of the sanitary protection zone (SPZ)[9]. Such a regulatory context presents new challenges to the management, management and line personnel of the refinery. Responsibility for the environmental well-being of the population of adjacent territories makes it necessary to consider and evaluate their environmental impacts and measures taken to reduce such impacts in the broad context of risk-based management, in the overall risk management system of the enterprise. It puts the task of reducing health risks among the priorities of effective corporate governance in accordance with the principles of environmental and social responsibility of ESG.

In the risk-oriented logic, ensuring the environmental safety of the population means that the actual value of the health risk created by industrial emissions at the border of the enterprise's sanitary protection zone (outside which residential areas are located) does not exceed the standard level. This health risk value is regarded as an acceptable residual risk[10]; the priority of corporate environmental management is to ensure the regulatory level of residual health risk at all stages of the life cycle of an enterprise / production facility: design, construction, operation (including construction of new facilities on the industrial site), decommissioning. The legislative consolidation of the mechanism of the best available technologies (BAT)[11] largely ensures this condition. Serious attention at the enterprises is paid to the implementation of special measures for the treatment of emissions into the atmosphere, wastewater treatment, waste recycling, which also contributes to the improvement of the environment in the old-developed regions and the reduction of negative impacts on public health. Meanwhile, the insufficiency of technological and environmental measures should be recognised, especially when it comes to the operation of existing enterprises or their reconstruction.

Practice shows that enterprises are often forced to solve the difficult task of achieving and confirming the acceptability of the residual health risk, that is, not exceeding the standard value. The situation is especially acute in the old-developed regions with historically developed fractional buildings, where residential areas are in close proximity to the industrial sites of existing enterprises. In fact, we are talking about the impossibility of reconstruction and modernisation, and sometimes the functioning of existing production due to the risks of exceeding the regulatory indicators of residual health risk, for example, during scheduled repairs, maintenance work, etc.

Under the current conditions undoubtedly there is a need for a serious adjustment in the approaches of the management of industrial enterprises, corporations and industrial groups when making decisions on the development of production activities – not only when choosing a site for new construction, but, above all, when operating existing industries with the possibility of their reconstruction and modernisation according to established environmental requirements. In fact, a universal set of consistently performed actions (procedures), integrated into the existing management systems is required, with the help

[6] https://www.iarc.who.int/wp-content/uploads/2018/07/pr221_E.pdf.

[7] Hazard categories I and II (Chapter VII SanPiN 2.2.1/2.1.1.1200-03 "Sanitary protection zones and sanitary classification of enterprises, structures and other objects").

[8] Art. 16, paragraph 6 of the Federal Law of May 4, 1999 No. 96-FZ (as amended on June 11, 2021) "On the Protection of Atmospheric Air".

[9] Sanitary protection zone is a special territory with a special mode of use, the size of which ensures the reduction of the impact of pollution (chemical, biological, physical) on the atmospheric air to the values established by hygienic standards, and for enterprises of hazard class I and II - to the values established by hygienic standards. standards, and up to the values of acceptable risk to public health (clause 2.1 SanPiN 2.2.1 / 2.1.1.1200-03 "Sanitary protection zones and sanitary classification of enterprises, structures and other objects").

[10] Recognition of the fact that no type of economic activity can be completely environmentally neutral ("presumption of environmental guilt").

[11] The Decree of the Government of the Russian Federation of December 24, 2014 No. 2674-r "On approval of the List of areas of application of the best available technologies", Decree of the Government of the Russian Federation of December 23, 2014 No. 1458 "On the procedure for determining technology as the best available technology, as well as the development, updating and publication of information -technical guides on best available technologies.

of which tasks will be solved to ensure the regulatory level of residual health risk at all stages of the life cycle of an enterprise / production facility.

Determination of approaches, development of specific methods for ensuring the normative level of residual health risk is a very difficult research task. Its solution requires the consideration of separate disparate methods of situational response as parts of a single system with the transfer of the target orientation of the analysis from the purely practical plane of effective decisions into the sphere of deep understanding of the issues related to ensuring the environmental safety of a person as the most important recipient of the negative environmental impacts of hazardous industrial facilities. Such understanding is carried out in the fundamental context of ensuring the viability (resilience) of anthropo-natural systems changed under the significant influence of hazardous industrial facilities [Fomenko, 2020].

Without claiming to exhaustively implement such theoretical concepts, as well as to fully cover all relevant aspects of sustainable corporate development within the framework of the ESG approach[12], the research was aimed at creating a decision-making algorithm to ensure the environmental safety of the population of oil refining areas based on the health risk assessment mechanism (hereinafter referred to as text – algorithm). They have been carried out over a number of years, taking into account the results of numerous design, consulting and research works carried out on the instructions of Russian oil refineries. They were taken into account as targeted projects (development of risk-based environmental management mechanisms [Avaliani et al., 2018], substantiation of the adequate boundaries of the SPZ of industrial enterprises and industrial centers [Fomenko et al., 2008], application of a risk-based approach to assessing and reducing vulnerability of ecosystems and the population[13]), as well as studies on a broader topic (identifying and assessing the actual level of negative environmental impact of industrial emissions from oil refineries in a specific urban situation, comparing it with regulatory requirements, determining measures to comply with standards and to organise appropriate control and monitoring of emissions[14]).

The algorithm is developed as a sequence of specific actions covering all stages of the life cycle of a production facility / industrial installation. This article provides a description of this algorithm, the detailed content of the stages, procedures and features of its application; specific mechanisms of health risk management and their practical significance are considered; the necessity of introducing the algorithm into the practice of corporate governance is substantiated.

1. Methods and information base

Methodologically, the research is based on the principles of risk management theory and the system of quality standards[15] and is widely used in corporate and public administration. In a generalised form, the risk management process is cyclical and includes: identification of hazards, their sources and created risks; risk assessment and their prioritisation according to the degree of significance; planning risk management measures (including avoidance, reduction of probability and/or materiality, acceptance, transfer, etc.); implementation of risk management measures (technological, operational, organisational and administrative, etc.); monitoring of residual risks. In relation to the environmental sphere, risk is interpreted as the probability of an occurring event that has adverse consequences for the natural environment and is caused by the negative impact of economic and other activities, natural and man-made emergencies[16].

In the field of ensuring the safety of the population from negative environmental impacts, the theory of health risks is being developed, the provisions of which, due to their high social significance and demand, are today the most normatively justified, with fixing in the legislative systems of a number of countries. At the same time, health risk assessment is considered as an obligatory part of the process of managing health risks from negative environmental impacts; moreover, it performs the function of monitoring the management process according to the relevant risk indicators (planned, current, normative, predictive). It should be noted that from a sanitary and environmental points of view, enterprises are responsible for the risk to society and are obliged to share it in proportion to their contribution [Olson, Desheng, 2008], which is most consistent with the modern risk management system[17] and represents the distribution of possible deviations from the expected results and goals due to the uncertainty of events in the external and internal environment of the enterprise. This vision of health risk is close to the majority of Russian researchers [Avaliani et al., 1996; Bolshakov et al., 1999; Avaliani, 2002; Onishchenko et al., 2003; Fomenko et al., 2010; Fomenko et al., 2018].

In accordance with the objectives of the study related to limiting the negative impact on the atmospheric air of

[12] https://corporatefinanceinstitute.com/resources/knowledge/other/esg-environmental-social-governance/.
[13] https://ntc-rik.ru/cases/8072/.
[14] The topics cover the environmental justification of new enterprises, new facilities as part of the reconstruction of existing industries, as well as the development of operational documentation for compliance with the environmental impact standards of existing enterprises, including environmental control and monitoring programmes.
[15] GOST R ISO 31000-2019 “Risk management. Principles and guidance” (national standard of the Russian Federation), ISO 31000:2018 “Risk management. Principles and guidance” (ISO 31000:2018 “Risk management – Guidelines”, IDT) (international standard).
[16] Federal Law of the Russian Federation of January 10, 2002 No. 7-FZ “On Environmental Protection”.
[17] By a modern risk management perspective, we mean a comprehensive, integrated and coordinated process within an organisation to manage all types of risk it faces.

oil refineries, methodological tools were used to assess the risk to public health when exposed to chemicals that pollute the environment, the provisions of which are normatively established by the "Guidelines for assessing the risk to public health when exposed to chemicals polluting the environment" R 2.1.10.1920-04 (approved by the Chief State Sanitary Doctor of the Russian Federation on March 5, 2004). This document prescribes a sequential (staged) study, including hazard identification, exposure assessment, assessment of the dose-response relationship, risk characterisation; in relation to each stage, the requirements for the composition and methodology of research, the data used are set out, and the obligation to perform an analysis of uncertainties is established. This ensures validation and verification requirements for the results obtained – intermediate and final.

The population health risk management algorithm is formulated in the logic of the sustainability of anthroponatural systems with a focus on the interconnectedness and interdependence of the processes and results of various stages of the life cycle of an enterprise, from pre-project studies and design to the decommissioning of a production facility [Beck, 1994; Von Weizsaecker, Wijkman, 2018; Fomenko, 2021; Fomenko, Fomenko, 2022].

Mathematical modeling of the dispersion of average annual concentrations was carried out using the Ecolog Unified Programme of air pollution estimation, version 4.5, the calculation block "Average". Calculations of carcinogenic and non-carcinogenic risks were carried out using MS Excel 2007 and the calculation block "Risks", version 4.5, which implements Guideline R 2.1.10.1920-04. Cartographic work was carried out using a computer geoinformation system (Arc Gis 10.1). As the main initial data for mathematical modeling, the current volumes of "Maximum Permissible Emissions", sections of the "List of Measures for Environmental Protection" and projects of sanitary protection zones, programmes for the medium-term development of enterprises were used; information on the climatic and weather characteristics of the studied territories for the location of oil refining enterprises was provided by the regional Federal State Budgetary Institution "Hydrometeorological Center of Russia".

This study is based on the results of a number of projects completed and currently being carried out on the instructions of oil refineries located in various geographical areas of Russia. The territories of their location are characterised by specific natural conditions (climatic characteristics, primarily wind and temperature regimes; terrain; background state of atmospheric air, etc.) and socio-economic conditions (urban planning situation, proximity and location of residential areas; the number of people exposed to potential environmental impact, risk groups, exposure to diseases, etc.). Specific quantitative indicators in this article are given based on the results of a specialised project for the implementation of risk-based management of the environmental safety of an oil refinery.

2. Results

The decision-making algorithm for ensuring the environmental safety of the population of oil refining areas based on the health risk assessment mechanism is a set of sequential procedures to ensure the standard indicator of the residual risk to the health of the population exposed to potential negative environmental impacts. The algorithm illustrates a single iteration (cycle) as part of a continuous process of managing a manufacturing enterprise at all stages of its life cycle, with special emphasis on those where the level of health risks created is especially sensitive to the results of decisions made. Estimated values of health risk each time (except in special cases) are determined by the cumulative impact of all industrial site facilities – existing and new construction.

Stage 1 – design. The actions are aimed at preventing additional health risks through the timely adoption of rational design decisions on the master plan, during which the locations of new facilities on the existing industrial site are reasonably detected (by considering several alternative options), and a detailed check of the adopted option is carried out in terms of the magnitude of the residual health risk at the border of the sanitary protective zone of the enterprise with the identification of the nature of the most significant hazards to public health which form the corresponding risks.

1. Justified choice of the location of environmentally hazardous facilities on the existing industrial site based on the analysis of alternative options.

During the development of the reconstruction project, three alternative options for the location of the new environmentally hazardous production facility were developed. The most preferable one – with significant savings in financial costs and location of the unit on a site with good logistics and communications – turned out to be blocked due to a risk factor (according to the results of an express assessment of health risks). The placement option with the minimum value of the increase in the value of the health risk due to the lack of communications on the site was characterised by unacceptably high financial costs. In fact, when choosing an acceptable option, only two alternatives were considered – option 2 and option 3, since option 1, despite the obvious technical and economic advantages, turned out to be unrealisable due to the expected excess of the standard value of the residual health risk. Of the three alternative options for locating an environmentally hazardous new construction facility, according to the results of a cumulative express assessment (Table 1), option 3 was adopted as a compromise between technical, economic and environmental factors.

Table 1
Results of express assessment of alternative options for the placement of an environmentally hazardous new construction facility

Object placement option	Characteristics of the option	Assessment by factors			Aggregate score
		technological	economic	ecological (health risks)	
Option 1	The facility is located in the southern part of the industrial site. The site with good logistics is adequately provided with communications (transport, resource, etc.). Significant savings in financial costs (compared to option 2 and especially option 3). Guaranteed excess of the regulatory level of residual health risk (HI > 1,0; HQ > 1,0; ICR > 10^{-4})	2	2	–	–
Option 2	The facility is located in the northern part of the industrial site. The site is not logistically secured, it is practically not equipped with communications (transport, resource, etc.). Significant financial costs, the highest of all three options. Guaranteed provision of the regulatory level of residual health risk at the level (HI < 0,001; HQ < 0,001; ICR < 10^{-6})	0	0	2	2
Option 3	The object is located in the central part of the industrial site. Logistically, the site as a whole is more secure than option 2; there are communications (transport, resource, etc.). Financial costs are set at a level much more acceptable than in Option 2. Compliance with the regulatory level of residual health risk is expected (HI < 0, 1; HQ < 0,1; ICR ≤ 10^{-6})	1	1	1	3

Note. The following estimated values are accepted in the table: "–" – the factor blocks the implementation of the variant; "0" – the minimum evaluation level; "1" – average estimated level; "2" – the maximum estimated level.

2. A detailed check of the accepted option for locating an environmentally hazardous facility in terms of the magnitude of the residual health risk at the border of the sanitary protection zone showed that there was no excess of the standard values. This result was presented as part of a set of project documentation for the reconstruction of the enterprise[18] and served as one of the conditions for a positive decision based on the results of the state expertise.

The results of the risk assessment revealed the main, most significant aspects of the formation of health risks (geographical, technological, toxicological):

- Geographical aspect – areas of the industrial site, which are characterised by the greatest magnitude of created health risks, have been identified. These are hygienically significant receptor points and areas of the industrial site with the maximum risk load - points on the border of the SPZ and the residential area in the south direction and the north-eastern part of the industrial site;
- Technological aspect – a list of production facilities has been developed, which form the highest exposure and risk load on the population. These are new construction facilities – hydrocracking and sulfur production units; existing facilities – installation 35-11/300-2, installation complex L-24-T-6, installation L-24-200-86;
- toxicological aspect – a list of the most dangerous priority chemical toxicants that form health risks

[18] In accordance with Decree of the Government of the Russian Federation of February 16, 2008 No. 87 (as amended on December 1, 2021) "On the composition of sections of project documentation and requirements for their content".

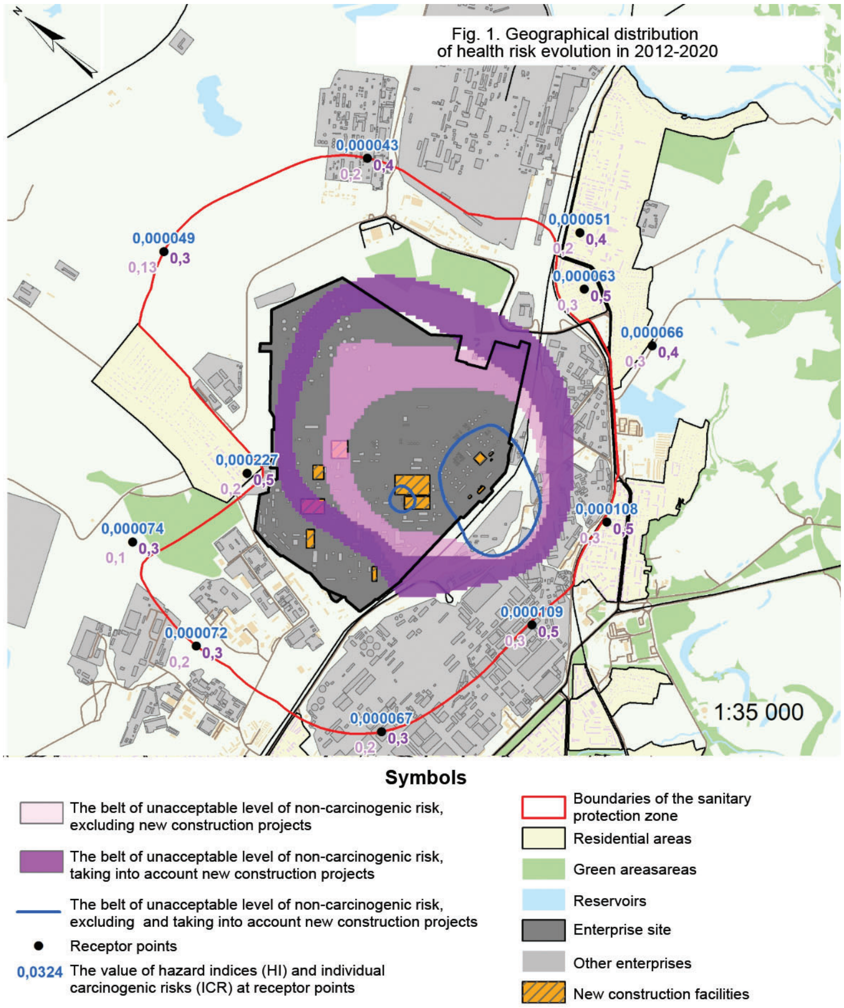


Fig. 1. Geographical distribution of health risk evolution in 2012–2020

has been compiled – 11 pollutants, including non-carcinogens: sulfur dioxide, nitrogen dioxide, hydrogen sulfide, kerosene, nitrogen oxide, vanadium pentoxide, xylene, benzene, black carbon (carbon black), benz/a/pyrene, ethylbenzene; carcinogens: benzene, carbon (soot), ethylbenzene, benz/a/pyrene.

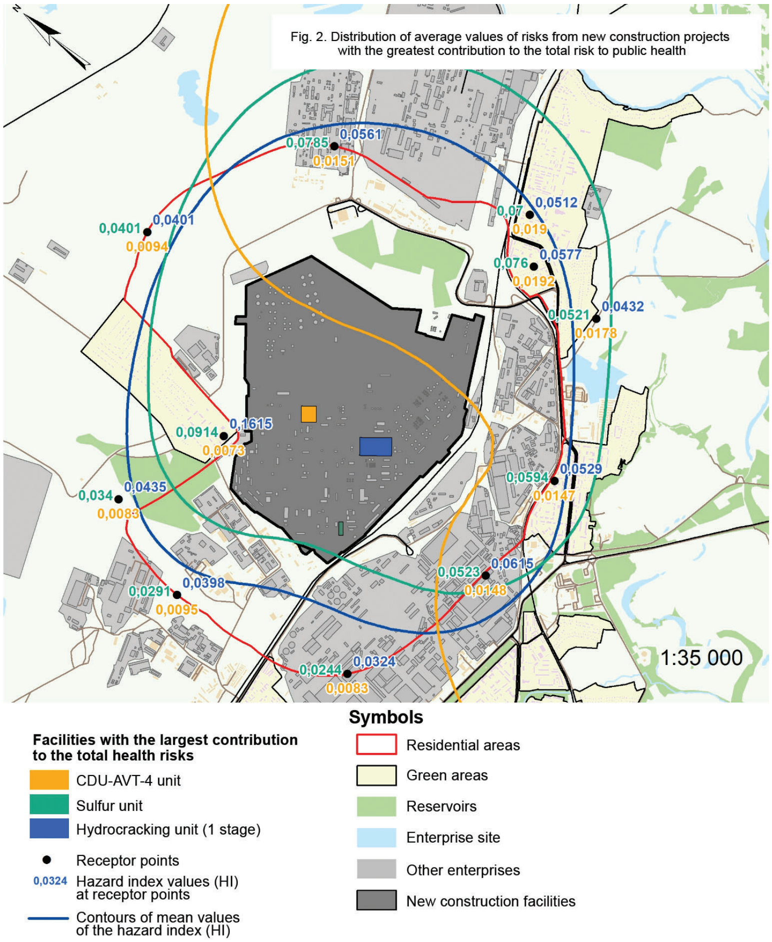
Stage 2 – construction. Typical actions within the framework of public health risk management are not envisaged at this stage. The construction process is not accompanied by the formation of significant risks to public health due to the relative short duration of the work being carried out, and also does not belong to objects of I-II hazard classes, subject to compliance with regulatory requirements for the performance of construction work and when taking environmental protection measures as part of project documentation according to the classification of industrial facilities and industries.

Stage 3 – operation. Risk management actions are aimed at reducing the likelihood of occurrence and minimising the damage from public health risks posed by the enterprise's production processes. The possibilities and optimal directions for reducing the significance of various aspects of the occurrence of hazards to public health – geographical, technological and toxicological – are determined. On this basis, the programmes of production control and production environmental control at the border of the sanitary protection zone are adjusted (according to the places of measurements, the schedule of measurements, controlled substances, etc.); plans for the implementation of investment measures (including environmental facilities) are being specified, taking into account their potential to reduce the level of health risk; technical operational documentation is being specified in order to minimise the likelihood of exceeding the standard indicator of residual risk to public health; measures are planned to comply with the established regime for the use of the territory of the sanitary protection zone.

The results of the study revealed sections of the SPZ border, the most dangerous in terms of the magnitude of health risks created, which are located in the southern and northeastern directions (Fig. 1). The most hygienically significant receptor points are concentrated on these sections of the SPZ boundary; in these directions, the areas of the industrial site are localised, where the most significant risk-generating impacts are created. As a detailed analysis of the risk situation dynamics showed, even if the orientation and configuration of the zones of distribution of non-carcinogenic risks (an oval with a northwest orientation) is preserved, the area of distribution of risks expands with the introduction of new objects. At the same time, the belt of unacceptable individual carcinogenic risk does not undergo significant changes. The obtained results of the geographic orientation of risk fields located within the boundaries of the SPZ, correlated with the general plan of the enterprise (in relation to the task of locating new construction facilities), show that it is unacceptable to place new production facilities in the northwestern part of the industrial site.

The objects of new construction are ranked according to the contribution to the general indicators of non-carcinogenic and carcinogenic risks formed at the border of the SPZ, in order to identify the most risky ones. The most risky production units include: among new construction projects there is a hydrocracking unit and a sulfur production unit; among the existing facilities there is the 35-11 / 300-2

Fig. 2. Distribution of average values of risks from new construction projects with the greatest contribution to the total risk to public health



installation, the L-24-T-6 installation complex, the L-24-200-86 installation. All these facilities are considered as the most risky on the industrial site and require special attention when planning health risk management measures. As a detailed analysis showed, the first place in terms of riskiness is occupied by new construction facilities – a hydrocracking unit (14.5% of the contribution to the total indicators of non-carcinogenic and carcinogenic risks) and a sulfur production unit (13.8%); the existing facilities are rated approximately at the same level: the oil distillation unit CDU-AVT-4 – 3.2%, the automated timed loading of light oil products with a vapour recovery unit – 2.6%, the tar visbreaking unit – 2.1%. For the rest of the new construction facilities, contributions to the total levels of health risk are less than 2% (Fig. 2).

The most dangerous chemical toxicants out of 27 pollutants identified in the company's emissions, according to the results of research, include 11 substances with non-carcinogenic (sulfur dioxide, nitrogen dioxide, hydrogen sulfide, kerosene, nitrogen oxide, vanadium pentoxide, xylene, benzene, black carbon (soot), benz/a/pyrene, ethylbenzene) and 4 substances with carcinogenic effects (benzene, carbon (soot), ethylbenzene, benz/a/pyrene).

Table 2

Results of clarifying the priority of planned investment activities, taking into account the potential to reduce the level of health risk

Investment measures, including for environmental purposes (as part of the current programme)	Priority, rank		Indicator of the potential total hazard index (HI) as a result of the implementation of the activity*
	without regard to health risks	taking into account health risks	
Activity A	1	6	0,0392
Activity B	2	7	0,052636
Activity C	3	8	0,449484
Activity D	4	9	1,355
Activity E	5	1	0,000605
Activity F	6	5	0,00345
Activity G	7	3	0,002074
Activity H	8	4	0,00284
Activity I	9	2	0,002038

* *For comparison*: the same indicator (total hazard index (HI) for the industrial site) for the current situation without the implementation of investment measures amounted to 6.00786.

The programmes of production control and industrial environmental control of the enterprise have been adjusted taking into account:

– location of the most risky sections of the SPZ boundary and localization of industrial site sections, from where the most significant risk impacts are created;
– priority in terms of health risks created by production facilities;
– priority riskogenic pollutants.

Based on the results of the study, control points were selected where the maximum risk load is formed, including at the border of the SPZ and at the border of residential development / the border of normalised territories. Changes have been made to the sampling schedules: for each new construction facility, during the first year after commissioning, the number of days of research on the full list of characteristic toxicants has been determined. The list of analyzed substances at control points has been corrected to include the main non-carcinogenic pollutants, as well as enterprise-specific pollutants.

Adjustment of the plan for the implementation of investment measures (including environmental facilities), taking into account the reduction in the level of health risk, showed (Table 2) that among the 9 planned activities, the greatest reduction in health risk will be achieved when implementing the following activities: D – priority 1, I –priority 2; the smallest decrease – in the implementation of activities: C – priority 8 and D – priority 9.

The list of decision-making factors to prioritise the implementation of investment plan activities (financing programmes and other documents) has been supplemented with an additional one, reflecting the share of health risk reduction in the overall total risk of the enterprise. As the practice of a number of oil refineries shows, measures to prevent the loss of marketable products, for example, the construction of a plant for hermetic loading of oil products into railway tanks, have a high potential to reduce health risks in comparison even with targeted environmental protection measures.

Clarifications have been made to the operational technical documentation. Technological regulations, schedules of repairs, maintenance and other documents were analysed from the point of view of reducing the likelihood of exceeding the regulatory level of residual health risk with strict adherence to technological standards and industrial safety standards, for example, the non-simultaneity of short-term burst releases of priority chemical toxicants due to dilution in time and localization on the industrial site of the respective emission sources.

Compliance with the established regime for the use of the territory of the SPZ includes a set of measures: (1) preventing the placement of industrial and civil facilities that pose a threat of exceeding the normative values of health risks at the border of the SPZ; (2) eliminating existing and preventing the formation of potential unauthorised waste dumps; (3) improvement and landscaping of territories, etc. Long-term practice for a number of enterprises in this direction (for example, the implementation of a project to justify the sufficiency of the size of the established unified sanitary protection zone of the Southern Industrial Hub of Yaroslavl) in accordance with the principles of social responsibility of business confirms the effectiveness and efficiency of such measures.

Stage 4 – decommissioning. At this stage we did not consider standard actions within the framework of public health risk management due to the lack of a request for this type of research, although such a procedure is provided for by law. The decommissioning process depends on the intended purpose and is carried out in accordance with the established regulatory documentation, including the termination of the existence of the sanitary protection zone[19]. When meeting current regulatory requirements, risk values do not exceed acceptable levels.

3. Discussion

The results of the studies performed and the analysis of the practical experience of oil refineries in ensuring the environmental safety of the population living in the territories of their location not only substantiated the need and confirmed the real possibility of successful actions in this direction, but also made it possible to develop and test an appropriate decision-making algorithm. The operation of the algorithm is based on the implementation of the methodology for assessing the risk to public health due to air pollution. Its introduction into the practice of enterprise management makes it possible to ensure compliance with the standard indicator of residual health risk at the border of the SPZ. Based initially on the identification and analysis of various aspects of the occurrence of hazards to public health – geographical, technological and toxicological aspects, the actions within the algorithm are aimed at minimising the residual risk both in the process of designing new enterprises and during their operation, especially when planning and placing on industrial site of new construction facilities (stages when the level of health risks is most sensitive to the decisions made). Monitoring of current indicators of health risks with analysis of their dynamics in comparison with standard values is an indispensable and repetitive element throughout the entire life cycle of an enterprise[20].

[19] Paragraphs 9-11 of the Decree of the Government of the Russian Federation of March 3, 2018 No. 222 (as amended on March 3, 2022) “On Approval of the Rules for Establishing Sanitary Protection Zones and the Use of Land Plots Located Within the Boundaries of Sanitary Protection Zones”.

[20] It is carried out in accordance with the Methodology for express assessment of public health risk by chemical factor (https://risk.ntc-rik.ru/). This technique can be used for preliminary approximate calculations by employees of the environmental service of the enterprise using a specialized software package. LLC Scientific and Technical Center “Resources and Consulting” was registered, a certificate of registration of a computer programme dated April 16, 2019 No. 2019614934.

Health risk management is implemented using the following tools:

at the design stage:

– avoidance or minimisation of risk, as a result of (1) a reasonable choice of the option of locating new facilities on the industrial site of an existing enterprise, (2) reasonable adoption of planning decisions on the placement of environmentally hazardous production facilities on the industrial site of a new enterprise being designed;
– reducing the level of health risk by reducing potential damage and/or reducing the likelihood of risk arising as a result of the use of technologies whose environmental impacts correspond to the level of BAT, as well as environmental measures that are effective in terms of reducing health risks;

at the stage of operation:

– reduction of health risks by reducing the likelihood of a risk situation as a result of increasing the efficiency of production control systems and industrial environmental control (clarification of the location of measurement points, measurement schedule, list of controlled substances);
– reducing the level of health risk by reducing potential damage and/or reducing the likelihood of risk materialisation as a result of (1) changing the priority of the implementation of investment measures, including environmental purposes, taking into account the magnitude of reducing the level of health risks, (2) clarifying operational requirements to minimise the level and the likelihood of risky releases by minimising the duration of simultaneous operation of environmentally hazardous installations, diversifying repair and maintenance work by time and location on the industrial site, etc., (3) ensuring compliance with the established regime for using the SPZ territory, primarily preventing the placement of industrial and civil purposes, posing a threat of exceeding the normative values of health risks at the border of the SPZ.

The results of the practical application of the algorithm confirm the effectiveness of the decision-making mechanisms embedded in it both in terms of compliance with applicable legal requirements, and in the broader aspect of ensuring sustainable business development in accordance with ESG approaches.

The relevance of the algorithm is associated with the widespread short-sighted practice of developing planning decisions (the initial stage of design – decisions on the master plan), guided mainly by economic and technological considerations, while actually ignoring the environmental aspects of the functioning of future facilities (including health risks), which further increases the threat of violations of the environmental legislation with corresponding very significant financial, economic and reputational costs. One should also take into account the low environmental performance of environmental protection measures at the operation stage, which is limited even at the construction stage by the selected technologies and localisation of sources of emissions and discharges of pollutants [Fomenko, 2021].

The algorithm is universal. It can be used in relation to existing production facilities and new construction facilities as part of projects for the reconstruction and modernization of enterprises. It is also effective in the implementation of investment projects for the construction of new industrial enterprises. The scope of its application is not determined by industry specifics – it can be used in the management practice of any enterprise or industrial company, especially those that have environmentally hazardous production facilities on their balance sheet. And finally, the logic of the algorithm and the sequence of actions laid down are relevant not only in relation to chemical pollution of atmospheric air, but also in situations of health risks from acoustic and electromagnetic effects, from pollution of consumed water.

In general, it should be emphasised that, in accordance with the logic of risk-based management, the risks to the health of the population of adjacent territories from environmental impacts created by the enterprise should be integrated into the overall risk management system of the enterprise (along with risks of industrial safety, financial, operational, climatic, etc.). Obviously, within the framework of the risk management system, the created health risks can be identified as risks of non-compliance with the established legislative requirements in the field of ensuring the environmental safety of the population. Nevertheless, it is undoubted that indicators characterising the riskiness of an enterprise for the population should be included in the decision-making process in the field of risk management, strategic and financial planning, and current operational management.

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