UDC 614.71; 614.78
DOI: 10.21668/health.risk/2024.1.01.eng

Read online

Research article

OPTIMIZATION OF REGULATORY ACTIONS BASED ON A DIFFERENTIATED APPROACH TO MANAGING AMBIENT AIR QUALITY AND HEALTH RISKS

**N.V. Zaitseva[1,2], S.V. Kleyn[1,2], D.A. Kiryanov[1],
A.M. Andrishunas[1], V.M. Chigvintsev[1], S.Yu. Balashov[1]**

[1]Federal Scientific Center for Medical and Preventive Health Risk Management Technologies, 82 Monastyrskaya St., Perm, 614045, Russian Federation
[2]Russian Academy of Sciences, Department of Medical Sciences, 14 Solyanka St., Moscow, 109240, Russian Federation

The study focuses on substantiating the most optimal regulatory actions aimed to minimize health risks caused by airborne exposures within Rospotrebnadzor activities including the Clean Air Federal project and the ongoing experiment on setting quotas for emissions. The aim of this study was to comparatively assess effectiveness of regulatory actions as regards specific subjects (exemplified by heat-power engineering objects) with or without use of differentiated approaches to managing ambient air quality and health risks.

We analyzed a database on priority sources of ambient air pollution in an analyzed area; performed a hygienic assessment of ambient air quality relying on computed data and also estimated contributions made by specific chemicals and objects to the total pollution; calculated population health risks; implemented an algorithm for substantiating optimal regulatory actions aimed to mitigate health risks under airborne exposures; comparatively analyzed activities stipulated by the Complex plan and suggested optimal regulatory actions identified by solving the optimization task. We conducted a reconnaissance stage-by-stage assessment of effectiveness of air protection activities over 2019–2023 relying on hygienic indicators and risk levels.

As a result, we established that implementation of air protection activities and a reduction in total emissions of more than 20 pollutants by heat-power engineering objects would not ensure significant improvement of environmental conditions in the analyzed area considering their share contributions. Safe standards would still be violated in residential areas with levels of chemicals reaching 6.25 single MPL and 7.0 average annual MPL. An optimal sufficient result, considering this share contribution, would be a reduction in emissions from all heat-power engineering objects by 3.47 thousand tons of 10 specific chemicals. This is lower than a reduction planned within the Complex plan on total emission reduction (18.1 thousand tons). To ensure conformity with safe standards that stipulate chemical levels in ambient air and to achieve permissible risk levels, it is necessary to apply a differentiated approach to reductions in emissions (by 1.06 thousand tons overall), which targets specific chemicals, at other sources of ambient air pollution.

Use of a differentiated approach to selecting optimal regulatory actions as regards all sources of ambient air pollution considering their share contributions will make it possible to define priority environmental protection activities, adjust the Complex plans and ensure conformity with safe standards and permissible risk levels in all residential areas.

Keywords: *ambient air quality, Clean Air Federal project, Complex plan of air protection activities, pollutant emissions, experiment of setting quotas, optimization task, contributions, safe standards, health risk, effectiveness of activities.*

Nina V. Zaitseva – Academician of the Russian Academy of Sciences, Doctor of Medical Sciences, Professor, Scientific Director (e-mail: znv@fchisk.ru; tel.: +7 (342) 237-25-34; ORCID: https://orcid.org/0000-0003-2356-1145).

Svetlana V. Kleyn – Professor of the Russian Academy of Sciences, Doctor of Medical Sciences, Head of the Department for Systemic Procedures of Sanitary-Hygienic Analysis and Monitoring (e-mail: kleyn@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-2534-5713).

Dmitrii A. Kiryanov – Candidate of Technical Sciences, Head of the Department for Mathematical Modeling of Systems and Processes (e-mail: kda@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-5406-4961).

Alena M. Andrishunas – Researcher at the Department for Systemic Procedures of Sanitary-Hygienic Analysis and Monitoring (e-mail: ama@fchisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-0072-5787).

Vladimir M. Chigvintsev – Candidate of Physical and Mathematical Sciences, Researcher at the Situation Modeling and Expert and Analytical Management Techniques Laboratory (e-mail: cvm@fchisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-0345-3895).

Stanislav Yu. Balashov – Senior Researcher – Head of the GIS group of the Laboratory of Integrated Sanitary Analysis and Examination Methods (e-mail: stas@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-6923-0539).

Legislation on ambient air protection plays the key role in providing environmental safety and sanitary-epidemiological wellbeing. Several instruments are fixed in it to accomplish state regulation of negative effects on the human environment. Establishing safety standards and limits of pollutant emissions for industry, motor transport and other pollution sources is one of the most significant elements in the sphere. The RF President Order dated May 07, 2018 No. 204 On National Goals and Strategic Tasks of The Russian Federation Development for the Period up to 2024 and implementation of the Ecology National project and the Clean Air Federal project have established target levels, which are to be achieved by decreasing ambient air pollution [1, 2].

To perform more effective control and reduce emissions of harmful chemicals into ambient air, an experiment on setting quotas for industrial emissions started on January 01, 2020 in Russia; it is planned to have been completed by the end of 2026. The experiment is being accomplished in accordance with the Federal Law issued on July 26, 2019 No 195-FZ[1], which stipulates setting fixed quotas of emissions for industrial enterprises as well as mechanisms and instruments for control and adherence to established limitations. The aim of this experiment is to search for optimal solutions that facilitate reductions in pollutant emissions into ambient air based on aggregated calculations of dispersion and health risk assessment. This is an important step towards sustainable development and environmental protection [3–6].

Thus, at present an experiment is being accomplished in order to improve ambient air quality in cities participating in the first stage of the Clean Air Federal project (12 cities overall). Its aim is to reduce total chemical emissions into ambient air (radioactive substances excluded) by 20 % (tons/year) by 2024 against 2017[1] [7]. Modeling of pollutant dispersion and assessment of ambient air pollution in these 12 cities covers approximately 50 thousand industrial emission sources of various types and configurations, emissions from motor transport at more than 3.3 thousand sections of traffic networks and more than 1.6 thousand of autonomous heat supply sources [3, 8]. According to the RF Government Order issued on July 07, 2022 No. 1852-r[2], the number of cities participating in the experiment grew by 29 thereby extending the list of pilot territories. The aim of this experiment is to reduce amounts of hazardous pollutant emissions by almost two times by 2030 against 2020 [9].

In order to implement relevant activities within the Clean Air Federal project, Complex plans of activities on reducing emissions of priority pollutants into ambient air have been developed and approved by the RF Government for each territory included into the experiment. It is noteworthy that the Complex plans developed for the first twelve cities stipulate a reduction in total emissions for each territory for the whole set of chemicals.

This wide-scale experimental approbation takes place for the first time in our country. It allows testing methods for modeling ambient air pollution and using their results in making

[1] O provedenii eksperimenta po kvotirovaniyu vybrosov zagryaznyayushchikh veshchestv i vnesenii izmenenii v otdel'nye zakonodatel'nye akty Rossiiskoi Federatsii v chasti snizheniya zagryazneniya atmosfernogo vozdukha: Federal'nyi zakon ot 26.07.2019 № 195-FZ [On accomplishing the experiment on setting quotas for emissions of pollutants and making alterations into specific legal acts of the Russian Federation regarding reduction of ambient air pollution: The Federal Law issued on July 26, 2019 No. 195-FZ]. *KonsultantPlus*. Available at: https://www.consultant.ru/document/cons_doc_LAW_329955/ (February 14, 2024) (in Russian).

[2] Ob utverzhdenii perechnya gorodskikh poselenii i gorodskikh okrugov s vysokim i ochen' vysokim zagryazneniem atmosfernogo vozdukha, dopolnitel'no otnosyashchikhsya k territoriyam eksperimenta po kvotirovaniyu vybrosov zagryaznyayushchikh veshchestv (za isklyucheniem radioaktivnykh veshchestv) v atmosfernyi vozdukh na osnove svodnykh raschetov zagryazneniya atmosfernogo vozdukha: Rasporyazhenie Pravitel'stva RF ot 7 iyulya 2022 g. № 1852-r [On Approval of the List of Urban Settlements and Districts with High and Extremely high Levels of Ambient Air Pollution, Which Are Added to the List of Territories Covered by the Experiment on Setting Quotas of Pollutant Emissions (Radioactive Substances Excluded) into Ambient Air Based on Aggregated Calculations of Ambient Air Pollution: the RF Government Order issued on July 07, 2022 No. 1852-r]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/351103411 (February 17, 2024) (in Russian).

specific targeted managerial decisions on development, control, and effectiveness of programs within the system for establishing safety standards, renewal of transport infrastructure and urban development in general. In future, these approaches and obtained results are planned to be used on other territories in the RF with high levels of ambient air pollution.

According to State Reports[3], the total emissions equaled 22,205.1 thousand tons in the Russian Federation in 2022. Of them, approximately 77 % were emitted by economic entities operating in various industries. The list of cities where the air pollution index (API) was above 14 (very high) included 40 cities with total population more than 10.4 million people. One third of the cities in the list are located in the eastern part of the country in the Siberia and Far East Federal Districts (SFD and FEFD respectively). Permissible chemical levels in ambient air are established to be violated considerably in these two Federal Districts (actual levels reaching up to 5 MPL): on average, violations accounted for 0.25 % air samples in the FEFD and 0.16 % for the SFD. Most common pollutants include benzo(a)pyrene, particulate matter $PM_{2.5}$ and PM_{10}, formaldehyde, particulate matter, carbon oxide, carbon (soot), hydrogen sulphide, ammonia, nitrogen oxides, sulfur dioxide, hydrogen fluoride, and various metals such as manganese, nickel and others. These chemicals occur in ambient air due to large metallurgical and chemical plants and heat-and-power engineering objects that operate quite actively in these areas. Some of them are city-forming enterprises or socially significant objects that are important for life support of local communities [10, 11].

Given that, development of optimal regulatory actions aimed to reduce ambient air pollution with priority chemicals should rely on a system for compliance with safety criteria including health risk levels, minimization of health harm and limitations of excessiveness and economic inexpedience of implemented activities [12–16]. To provide the sanitary-epidemiological service with practical science-based tools, a methodology MR 2.1.6.0320-23[4] was developed in 2023, which is eligible for selecting optimal regulatory actions aimed to minimized airborne health risks. This methodology does not replace the procedure for setting emission quotas; rather, it allows estimating whether suggested environmental protection activities are adequate in a given situation.

The aim of this study was to comparatively assess effectiveness of regulatory actions as regards specific subjects (exemplified by heat-power engineering objects) with or without use of differentiated approaches to managing ambient air quality and health risks.

Materials and methods. To achieve the stated aim, we compared activities outlined in the Complex plan[5] and regulatory actions established on the basis of differentiated approaches as a result of solving the optimization task on a pilot territory in accordance with the algorithm described in the Methodical guidelines 2.1.6.0320-23[4] [4].

According to the MR 2.1.6.0320-23, selecting optimal actions aimed to minimize airborne health risks involves identification of calculated

[3] O sostoyanii i ob okhrane okruzhayushchei sredy Rossiiskoi Federatsii v 2022 godu: Gosudarstvennyi doklad [On the state and protection of the environment in the Russian federation in 2022: the State Report]. Moscow, Ministry of Natural Resources and Environment of the Russian Federation; M.V. Lomonosov's Moscow State University, 2023, 686 p. (in Russian); O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiiskoi Federatsii v 2022 godu: Gosudarstvennyi doklad [On sanitary-epidemiological welfare of the population in the Russian Federation in 2022: the State Report]. Moscow, the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2023, 368 p. (in Russian).

[4] MR 2.1.6.0320-23. Poryadok opredeleniya perechnya prioritetnykh zagryaznyayushchikh veshchestv i perechnya kvotiruemykh ob"ektov s obosnovaniem optimal'nykh napravlenii reguliruyushchikh vozdeistvii po minimizatsii aerogennykh riskov zdorov'yu naseleniya [The procedure for identifying the list of priority pollutants and objects mandatory for setting emission quotas along with substantiating optimal regulatory actions aimed to minimize airborne health risks], 2023, 36 p. (in Russian).

[5] Kompleksnyi plan meropriyatii po snizheniyu vybrosov zagryaznyayushchikh veshchestv v atmosfernyi vozdukh v g. Krasnoyarske, utv. Zamestitelem Predsedatelya Pravitel'stva RF 19.04.2022 № 3968p-P11 [The Complex Plan of activities on reduction of pollutant emissions into ambient air in Krasnoyarsk, approved by the Deputy Head of the RF Government on April 19, 2022 No. 3968p-P11]. *Professional'noe izdatel'stvo LLC.* Available at: https://www.profiz.ru/upl/Красноярск%2C%20план.pdf (February 17, 2024) (in Russian).

reference points or points of local peaks in densely populated residential areas. Such points describe chemical hazards under acute and chronic exposure. Use of the optimization method makes it possible to identify specific economic entities and establish differentiated reductions in emissions of priority chemicals. This ensures compliance with safety standards including health risks levels on an analyzed territory. Optimization based on branch algorithms and algorithms of linear programming boundaries is aimed at finding optimal conditions with the use of a target function, which includes a minimal reduction in emissions in the whole residential area. The total minimal reduction in pollutant emissions at all objects under regulation (without considering economic characteristics of implemented activities) is assumed to lead to minimal technological changes and ensure compliance with safety standards and acceptable levels of health risks in residential areas due to implementation of relevant optimal regulatory actions.

Krasnoyarsk was chosen as a pilot territory for testing methodical approaches and implementing the algorithm for solving the optimization task. The city is included into the Clean Air Federal project; it is a large economic, industrial and energy-producing center where electric and heat energy is produced, transported and sold to end customers. Heat-and-power engineering is among leading industries on the analyzed territory and this gave grounds for more profound analysis of activities with their focus on heat-power engineering objects (HPEO) in this study.

Thus, in Krasnoyarsk, the total volume of pollutant emissions, both from stationary and mobile sources, is above 140.8 thousand tons per year. Of them, approximately 55 thousand tons are emitted by heat-power engineering objects that are parts of the unified centralized system. It consists of thermal power stations, coal-fueled and electrical boiler houses supplying heat for the city population. In addition to that, 40 residential blocks in the city are equipped with autonomous heat supply sources that supply heat to houses and some social objects and emit approximately 5.3 thousand tons per year.

The task was to assess effectiveness of investment programs and complex plans related to minimization of health risks and hazards caused by energy-producing enterprises for people living in Krasnoyarsk. To do that, we used initial data taken from the systematized database on stationary and mobile emission sources in Krasnoyarsk (the data were provided by the Ministry of Natural Resources and submitted to Rospotrebnadzor as an electronic report following the official enquiry). The database contained information about 6411 sources of 251 pollutants: 5977 emission sources (3597 regulated and 2422 unregulated) that belonged to 807 enterprises and organizations operating in the city, 171 autonomous heat supply sources (residential areas with private houses) and 263 sections of the city traffic network.

The data base on heat-power engineering objects included 302 enterprises that either produced and distributed energy or had heat supply sources at their facilities, such as major heat supply sources (thermal power stations (TPS) 1, 2 and 3) and 171 autonomous heat supply sources that emitted 55 chemicals. Figure 1 provides geographic location of heat-power engineering objects in Krasnoyarsk (a situation map).

In order to solve the optimization task, data arrays were prepared with levels of occurring calculated concentrations in residential areas and levels of occurring health risks. Dispersion of chemicals from an emission sources in ambient air was calculated using Ekolog-Gorod 4.6 Unified Program for Calculating Ambient Air Pollution. Health risks caused by chemical pollutants in ambient air emitted by both all sources and exclusively by heat-power engineering objects and autonomous heat supply sources were assessed in accordance with the Guide R 2.1.10.1920-04[6] by accomplishing all necessary steps in relevant sequence. Obtained results were visualized by using ArcView 3.2 and ArcGIS 9.3.1 software.

[6] R 2.1.10.1920-04. Human Health Risk Assessment from Environmental Chemicals. Moscow, the Federal Center for State Sanitary and Epidemiological Surveillance of RF Ministry of Health, 2004, 143 p. (in Russian).

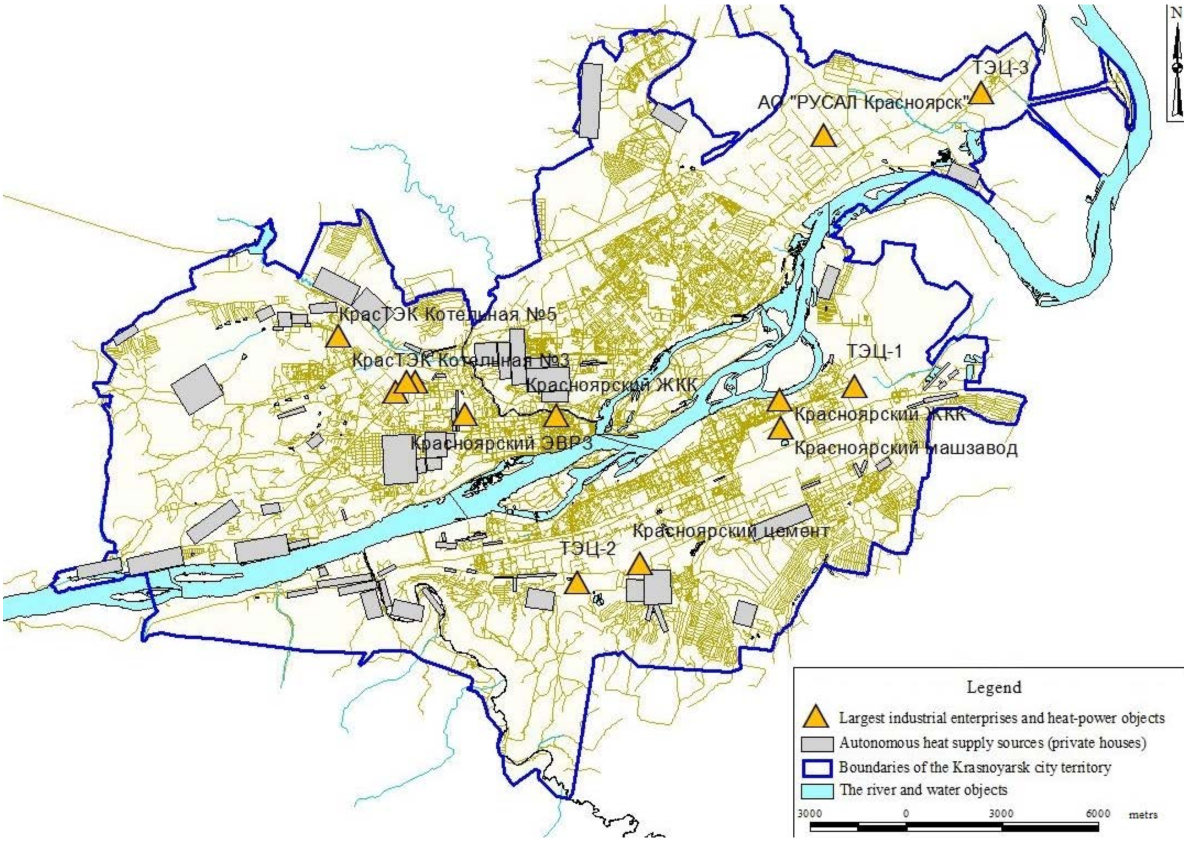

Figure 1. The map showing locations of heat-power engineering objects within the Krasnoyarsk city territory

We conducted a reconnaissance stage-by-stage assessment of effectiveness of air protection activities over 2019–2023 relying on current changes in ambient air quality at four monitoring posts of Rospotrebnadzor per 37 pollutants and occurring levels of health risks.

Results and discussion. Investigations and hygienic analysis of ambient air quality based on calculated dispersion of pollutants from all sources on the analyzed territory revealed that safety standards were violated in residential areas as per 17 chemicals: manganese and its compound (up to 1.03 single MPL, up to 11 average annual MPL), benzo(a)pyrene (up to 4.5 average annual MPL), nitrogen dioxide (up to 6.3 single MPL, up to 2 average annual MPL), carbon (soot) (up to 1.6 single MPL), carbon oxide (up to 3.9 single MPL), gaseous fluorides (up to 1.4 single MPL), chlorine (up to 1.6 single MPL, up to 2.7 average annual MPL), benzene (up to 2.1 single MPL), phenol (up to 2.1 single MPL), particulate matter (up to 3.2 single MPL), dust with 20 to 70 % SiO_2 (up to 5.2 single MPL), dust with SiO_2 below 20 % (up to 1.6 single MPL), abrasive dust (up to 2.0 single MPL), prop-2-en-1-al (up to 1.5 single MPL), sodium hydroxide (up to 1.1 single MPL), sulfur dioxide (up to 1.1 single MPL), butadiene and (up to 1.1 average annual MPL). It is worth noting that solely heat-power engineering objects cause violations of safe standards for ambient air quality in residential areas as per nitrogen dioxide (up to 3.04 single MPL), carbon (up to 1.52 single MPL), carbon oxide (up to 3.84 single MPL), particulate matter (up to 3.19 single MPL), inorganic dust: 70–20 % SiO_2 (up to 5.1 single MPL), inorganic dust: SiO_2 below 20 % (up to 1.1 single MPL).

Practically all people living in the city (89 %) are exposed to elevated ambient air pollution from all emission sources: 1064.6 thousand people are exposed to more than 1 single MPL and 351.9 thousand people to more than 1 average annual MPL.

Established calculated levels under acute inhalation exposure create elevated hazard quotients per six chemicals: nitrogen dioxide, benzene, particulate matter, sodium hydroxide, buta-1,3-diene, and prop-2-en-1-al, up to 2.1–48.8 HQac. These risk levels result in higher likelihood of acute diseases of the respiratory organs, eyes, developmental disorders, diseases of the reproductive and immune systems and systemic effects, up to 4.1–49.8 HIac. Approximately 131.5 thousand people or 12.2 % of the city population live in areas with 'alerting' (hazard indexes are between 3 and 6) and 'high' (HI > 6) acute health risks.

Elevated hazard quotients are determined by six chemicals under chronic inhalation exposure: nitrogen dioxide, benzo(a)pyrene, manganese and its compounds, nickel oxide, buta-1,3-diene, and chlorine, up to 1.6–40.4 HQch. Effects of the foregoing chemicals create unacceptable risks for the respiratory system, central nervous and peripheral nervous system, reproductive, cardiovascular and immune systems, blood, and developmental processes, between 1.6 and 52.5 HIch (Figure 2). Overall, approximately 15.8 thousand people or 1.5 % of the city population live in areas with elevated health risks established as per aggregated calculations of pollutant dispersion.

Assessment of carcinogenic risks did not establish any elevated levels of the total individual carcinogenic health risk related to exposure to the analyzed chemicals in ambient air on the analyzed territory as per calculated data.

As can be seen in Figure 1, heat-power engineering objects (emission sources located at industrial enterprises, emissions from boiler houses and autonomous heat supply sources) are scattered near to or within residential areas in the city. Zones affected by them are determined by both even locations and low-height emission source able to create local ambient air pollution.

Contributions made by heat-power engineering objects to average annual ground concentrations were assessed for the whole city territory based on calculated data. This assessment revealed that contributions made by 55 analyzed chemicals varied between 1 and 99 % in different areas in the city; a significant contribution (more than 50 %) was made by chemicals, calculated levels of which were higher than the established safety standards (Table 1).

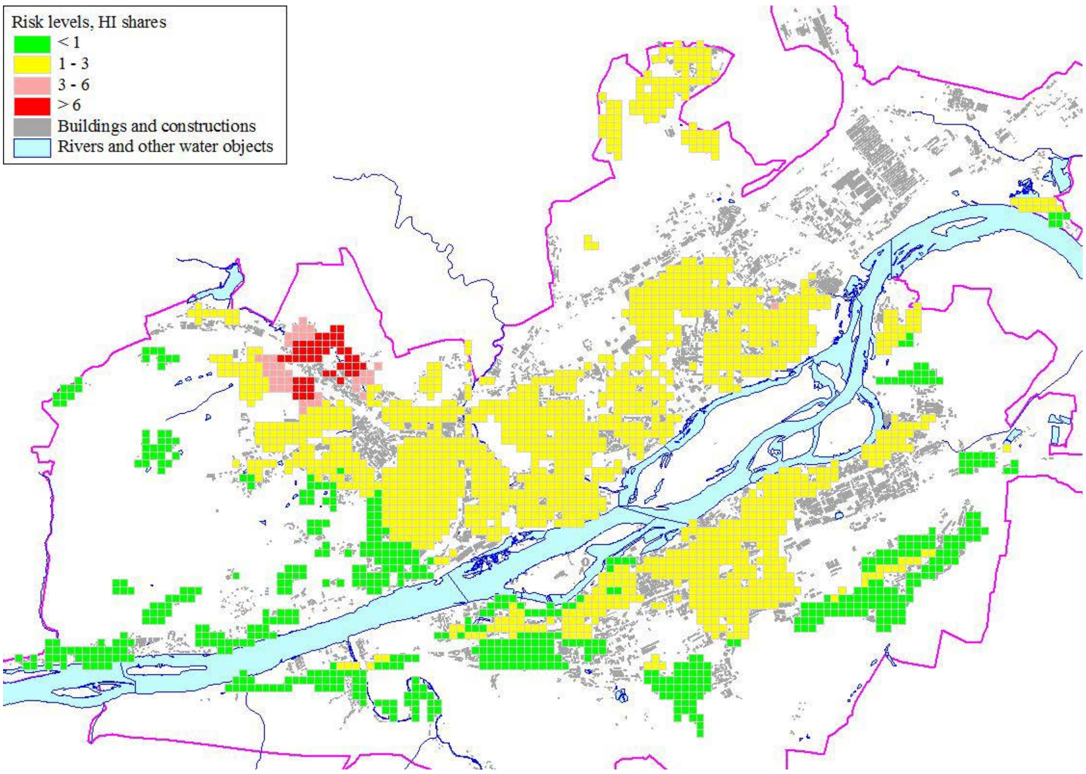

Figure 2. The map showing spatial distribution of non-carcinogenic Kchronic health risks for the respiratory organs based on calculated data, HIch percentages

Table 1

Data on contributions made by heat-power engineering objects (HPEO) to average annual ground concentrations in the city as a whole in residential areas: a fragment on some chemicals, calculated levels of which are higher than safety standards

Code	Chemical	Contributions of HPEO to the total gross emissions*	Contributions of HPEO to the average annual concentrations, %		
			Minimum	Medium	Maximum
301	Nitrogen dioxide (Nitrogen (IV) oxide)	69.3	4.17 %	22.77 %	66.41 %
328	Carbon (soot)	59.4	19.30 %	75.00 %	**92.70 %**
330	Sulfur dioxide (Sulfuric anhydride)	69.0	36.10 %	68.10 %	89.99 %
337	Carbon oxide	16.4	20.62 %	62.25 %	**93.04 %**
2902	Particulate matter	55.8	16.95 %	86.53 %	**99.59 %**
2908	Inorganic dust: 70–20 % SiO_2	89.3	39.09 %	87.84 %	**99.09 %**
2909	Inorganic dust: SiO_2 up to 20 %	7.9	2.35 %	25.54 %	87.50 %
2930	Abrasive dust (white corundum, monocrystalline alumina)	4.5	0.07 %	1.86 %	71.53 %

Note: * means total contributions made by only TPS-1, TPS-2, TPS-3, 35 boiler houses, and autonomous heat supply sources.

The total contribution made by heat-power engineering objects to health risks varied between 1 and 37 % for different target organs and systems.

A profound analysis of the Complex plan established that a goal was to reduce pollutant emissions from heat-power engineering objects by 42.6 thousand tons by 2024, or 22.3 % from the 2017 level. It should be achieved by implementing various technical, technological and organizational measures including TPS upgrading, decommissioning of coal-fueled boiler houses, moving people from dilapidated housing with stove heating, providing private houses with centralized heat supply or gas heating and some others. In particular, the Complex plan of air protection activities aimed at reducing emissions from heat-power engineering objects stipulates a reduction in emissions or a number of emission sources by Siberian Generating Company LLC, Krasnoyarskaya TPS-1, 35 municipal boiler houses and in dilapidated housing with stove heating.

In particular, Siberian Generating Company LLC plans to install an automated system for control of pollutant emissions into ambient air at its heat-power engineering objects, namely, thermal power stations in Krasnoyarsk. In addition to that, the company plans to add new generating capabilities to already existing ones at Krasnoyarskaya TPS-3 to balance heat loads after 35 ineffective coal-fueled boiler houses are decommissioned.

Ineffective coal-fueled boiler houses have been established to emit 52 pollutants typical for this economic activity. The Complex plan stipulates a reduction in total emissions from these 35 boiler houses by 7.7 % (10.8 thousand tons). Implementation of these measures is expected to reduce local single concentrations, which are higher than safe standards (more than 1.1 single MPL) in residential areas, for example, by 10 % per such pollutants as nitrogen dioxide and inorganic dust: 70–20 % SiO_2; still, their levels are going to remain at 1.1–4.4 single MPL. In particular, the implemented measures on emission reduction will result in a decrease in levels of inorganic dust: 70–20 % SiO_2 down to 1.0 single MPL and make it possible to remove 0.53 thousand people from as area with elevated pollution under acute inhalation exposure. Average annual concentrations will remain stable at the level of 1.1–7.0 average annual MPL.

Optimization approaches to selecting regulatory actions demonstrated that a reduction by 120.1 tons (or by 1.1 % of the total gross emissions from 35 coal-fueled boiler houses in 2017) as per 7 chemicals would be optimal considering the contribution made by these boiler houses into the total ambient air pollution. The foregoing seven chemicals include particulate matter, chromium, manganese and its compounds, carbon (soot), inorganic dust: 70–20 % SiO_2, inorganic dust: SiO_2 up to 20 %, and sulfur dioxide. Currently, their total emissions equal 241.9 tons, between 9 and 100 % (Table 2).

Thus, specifically, parameterized activities have been developed for only 12 ineffective coal-fueled boiler houses for which the Complex plan stipulates a 6.3 % reduction in the total emission (8.8 thousand tons) per 19 chemicals (Table 2).

The Complex plan also stipulates moving people from dilapidated housing with stove heating. This will reduce the total emissions by 0.22 % (0.3 thousand tons) of the 2017 level.

According to the aggregated database on sources of pollutant emissions on the analyzed territory, autonomous heat supply sources emit seven pollutants: nitrogen dioxide, nitrogen (II) oxide, sulfur dioxide, carbon oxide, benzo(a)pyrene, particulate matter, and inorganic dust: 70–20 % SiO_2. Currently, their total emissions are above 5.3 thousand tons (8.7 % of the total gross emissions from all heat-power engineering objects ion the analyzed territory).

Implementation of air protection activities within the Complex plan will lead to a slight decrease (by 0.01–0.03 single MPL) in the highest single levels of chemicals, which are higher than safety standards. These concentrations will remain at the level of up to 1.1–6.25 single MPL. Average annual levels of chemicals, which are higher than safety standards (up to 1.1–6.98 average annual MPL), will remain practically the same.

When solving the optimization task and within the differentiated approach to selecting regulatory actions, we established that it was optimal to reduce emissions of six chemicals by autonomous heat supply sources given their contribution to the total ambient air pollution. These six chemicals include sulfur dioxide, nitrogen dioxide, benzo(a)pyrene, inorganic dust: 70–20 % SiO_2, carbon oxide, and particulate matter. Their total emissions currently equal 1.4 thousand tons per year. To ensure compliance with the sanitary-hygienic standards for chemical levels and to achieve acceptable health risk levels in the total residential areas, it is necessary to reduce emissions of these six chemicals by 1–100 %. The overall reduction, given the contribution made by autonomous heat supply source to ambient air pollution, should be equal to 658.6 tons, which is 2.1 times higher than the reduction stipulated by the Complex plan (Table 3). Table 4 provides a fragment of the detailed data on reductions in emissions of some specific chemicals by autonomous heat supply sources according to the Complex plan and optimal reductions in emissions of the said sources recommended considering the optimization criterion.

Table 2

Comparative assessment of planned complex air protection activities aimed at reducing emissions of specific chemicals into ambient air and differentiating optimized regulatory actions at 12 coal-fueled boiler houses (tons/year)

Chemical	Complex plan, tons/year	Optimized regulatory actions	
		tons/year	Reduction against 2017, %
Chromium	0.0001	0.0017	9
Nitrogen dioxide	878.453	–	–
Nitrogen (II) oxide	142.734	–	–
Carbon (soot)	859.055	–	–
Sulfur dioxide	1101.932	–	–
Carbon oxide	5018.029	–	–
Inorganic dust: 70–20 % SiO_2	788.427	119.68	50
and other chemicals	25.778	0.000068	100
Total:	8814.408	119.7	1.3

Table 3

Comparative assessment of planned complex air protection activities and differentiated optimized regulatory actions aimed at reducing total emissions of specific chemicals into ambient air concerning autonomous heat supply sources (tons/year)

Chemical	Complex plan, tons/year	Optimized regulatory actions, tons/year
Nitrogen dioxide	6.777	18.01
Nitrogen (II) oxide	1.172	-
Sulfur dioxide	3.576	0.173
Carbon oxide	256.250	228.39
Benzo(a)pyrene	0.000	0.000049
Particulate matter	32.739	55.618
Inorganic dust: 70–20 % SiO_2	10.095	356.398
Total:	310.609	658.608

Table 4

A fragment of the complete list of autonomous heat supply sources which are subject to planned air protection regulatory actions according to the Complex plan and recommended optimal reductions in emissions by them

No.	Emitted pollutants that are subject to optimization	Emission mass (tons/year)	A share of a chemical in total emissions, %	A reduction in total emissions according to the Complex plan, %	Reductions in emissions as per results of solving the optimization task concerning the analyzed chemicals, %
	Autonomous heat supply sources in Badalyk settlement				
1	0703 Benzo(a)pyrene	1.73E-05	1.8E-05	–	100
	Autonomous heat supply sources in Peschanka settlement				
1	2908 Inorganic dust: 70–20 % SiO_2	12.397499	13.2	–	11
	Autonomous heat supply sources in Torgashino settlement				
1	0301 Nitrogen dioxide (Nitrogen (IV) oxide)	10.545777	2.1	–	100
2	2908 Inorganic dust: 70–20 % SiO_2	71.905526	14.4		46
	Autonomous heat supply sources in Laletino settlement				
1	0301 Nitrogen dioxide (Nitrogen (IV) oxide)	9.80651	2.1	16.2	36
2	0337 Carbon oxide	339.490704	74.1		37
3	2902 Particulate matter	34.52616	7.5		43
4	2908 Inorganic dust: 70–20 % SiO_2	58.956965	12.9		73

Currently TPS-1 emits 36 chemical pollutants into ambient air and its total emissions are 16 thousand tons. The Complex plan of activities aimed at reducing pollutant emissions into ambient air stipulates a reduction in emission of all chemical by this TPS by 7.0 thousand tons (43.7 %).

The differentiated approach to selecting optimal regulatory actions demonstrated that it was optimal to reduce emissions of only one chemical by TPS-1, given its contribution to ambient air pollution. This chemical is inorganic dust: 70–20 % SiO_2 with its contribution currently being 5.9 thousand tons (35 %) in the total emissions by TPS-1. To ensure compliance with the sanitary-hygienic standards for chemical levels and to achieve acceptable health risk levels in the total residential area (at 678 points involved in setting emission quotas), it is necessary to reduce emissions of inorganic dust: 70–20 % SiO_2 by 46 %, or 2.7 thousand tons, of the total emissions form this TPS.

Therefore, the Complex plan stipulates the total reduction in emissions form heat-power engineering objects by 18.1 thousand tons per more than 20 chemicals[7] (particulate matter, nitrogen dioxide, nitrogen (II) oxide, carbon (soot), sulfur dioxide, chromium, inorganic dust: 70–20 % SiO_2, inorganic dust: SiO_2 up to 20 % and others) (Table 5).

Table 5

Comparative assessment of planned complex air protection activities aimed at reducing pollutant emissions into ambient air and differentiated optimized regulatory actions at heat-power engineering objects (tons/year)

Action	Complex plan, tons/year	Optimization task, tons/year
35 boiler houses	10.8 thousand	0.12 thousand
Autonomous heat supply sources	0.3 thousand	0.65 thousand
TPS-1	7.0 thousand	2.69 thousand
Total:	18.1 thousand	3.47 thousand

The results obtained by solving the optimization task clearly indicate that it is optimal to reduce emissions from heat-power engineering objects per 10 chemicals only (carbon, nitrogen dioxide, benzo(a)pyrene, particulate matter, chromium, sulfur dioxide, carbon oxide, manganese, inorganic dust: 70–20 % SiO_2, SiO_2 up to 20 %) between 1 and 100 %. The total reduction will equal 3.474 thousand tons a year, which is 5.2 times lower than stipulated by the Complex plan; still it will ensure compliance with the existing safety standards and achieving acceptable levels of health risks.

Implementation of air protection activities and reductions in the total emissions from heat-power engineering objects stipulated in the Complex plan will not significantly improve living conditions on the analyzed territory given the estimated contributions made by them to ambient air pollution. On the contrary, recommended differentiated optimal reductions in emissions estimated as per the results of solving the optimization task will ensure the relevant positive changes.

Moreover, additional evidence has been provided to support the above conclusions, namely, the results obtained by predictive health risk assessment. Implementation of air protection activities stipulated by the Complex plan is expected to bring about a slight positive trend, which is a 1.1–1.2 times decline in risks of diseases of the nervous, hematopoietic, cardiovascular, reproductive, immune, and respiratory systems. Carcinogenic risks mostly occurring due to exposure to formaldehyde will remain stably high (reaching $3.28 \cdot 10^{-4}$). Acute and chronic risks for target organs and systems, including the respiratory, cardiovascular and immune systems, eyes, blood, and developmental processes, will be equal to 6.5–25.5 HIac and 11.9–22.6 HIch. Implementation of activates within the Complex plan will make it possible to move approximately 50 thousand people from zones with unacceptable acute health risks and 120 thousand people from zones with unacceptable chronic health risks into ones with minimal (target) health risks [8].

To ensure compliance with the safety standards for chemical levels in ambient air (1 single MPL, 1 average annual MPL) and to achieve acceptable levels of health risks (1 HQ, 3 HI, $CR \leq 1 \cdot 10^{-4}$, $CR_T \leq 1 \cdot 10^{-4}$) on the analyzed territory, it is necessary to achieve differentiated reductions in emissions not only from heat-power engineering objects but also from other emission sources (economic entities and motor transport) by 1.06 thousand tons overall, including nitrogen dioxide, by 0.941 thousand tons (between 6 and 100 % at different sources); carbon, by 0.00128 thousand tons (between 19 and 100 %); sulfur dioxide, by 0.0021 tons (100 %); benzo(a)pyrene, by 0.87 tons (78–100 %); particulate matter, by 0.262 tons (24–47 %); carbon oxide, by 0.156 tons (100 %); inorganic dust: 70–20 % SiO_2, by 42.93 tons (7–100 %); inorganic dust: SiO_2 up to 20 %, by 0.61 tons (14–100 %); manganese, by 0.65 tons (86–93 %).

Reconnaissance assessment was performed to estimate effectiveness of air protection activities relying on current changes in ambient air quality per all chemicals at four monitoring posts of Rospotrebnadzor over

[7] The number of chemicals has been identified only for 12 boiler houses and autonomous heat supply sources, for which parameterized data on planned measures have been provided.

2019–2023. It demonstrated a decrease in the highest single concentrations of five analyzed chemicals: formaldehyde, gaseous fluorides, ammonia, carbon oxide, ethyl benzene (the decrease rate varied between 63.9–1.79 %) down to 0.46–2.75 single maximum MPL. Still, a certain growth in single concentrations was detected for seven chemicals: nitrogen dioxide, nitrogen (II) oxide, particulate matter, PM_{10}, $PM_{2.5}$, hydroxybenzene, dimethyl benzene by 1.8–8.5 times up to 1.87–5.71 single MPL. A decrease was also established in average annual levels of two chemicals, formaldehyde and benzene (the decline rate varied between 94.1–54.9 %) down to 0.21–0.64 average annual MPL and a certain growth was established for five chemicals: nitrogen dioxide, benzo(a)pyrene, particulate matter, $PM_{2.5}$, and PM_{10} (the growth rate is 1.2–5.1 times) up to 1.1–2.36 annual average MPL.

The established trends as changes in exposure manifested themselves in levels of created health risks. Over 2019–2023, a decline was established in individual carcinogenic risk levels caused by exposure to airborne benzene (by 89.8 %) down to $1.42 \cdot 10^{-5}$, hazard quotients under short-term (acute) inhalation exposure to formaldehyde and benzene (by 49.8–79.5 %) down to 1.2 HQac; a certain growth was established for PM_{10}, $PM_{2.5}$ and particulate matter in general (by 60.5–42.4 %) up to 11.3 HQac. Over the analyzed 5-year period, there was a decline in hazard quotients of non-carcinogenic effects under chronic inhalation exposure to benzene (by 89.8 %) down to 1.41 HQch and a certain ascending trend for hazard quotients associated with nitrogen dioxide, benzo (a)pyrene, particulate matter, $PM_{2.5}$ and PM_{10} by 2.1–6.6 times up to 2.76 HQch.

At present, many research articles report rather ambiguous results of the ongoing experiment. Thus, implementation of the Complex plan on the pilot territories has demonstrated that, according to social-hygienic monitoring data, ambient air quality still does not comply with the mandatory sanitary-hygienic requirements in some cities [17–20]. Practical experience indicates that many tools for state regulation of ambient air pollution that are fixed in the legislation have a theoretically high potential but are hardly efficient in practice. This is due to high expenditure on environmental protection, low motivation of economic entities to reduce negative effects on ambient air, errors and miscalculations in planning, making and implementing decisions significant for environmental protection [21–24].

A study by A.V. Komarova and E.A. Maklakova [7] has demonstrated that quotas set for pollutant emissions do not consider suggestions made by enterprises or technological and economic expedience of reducing emissions at sources with preset quotas. Moreover, several important factors are neglected such as uneven and non-simultaneous work of different equipment, changes in work regimes and different stages in metallurgical production processes (non-stationary emissions).

Up-to-date scientific research should involve changes in approaches to regulation of ambient air pollution. Therefore, it is advisable to concentrate efforts on reducing emissions of priority pollutants and health risk factors considering their contributions to the overall pollution instead of reducing the total emission volumes by 22 %. Priority pollutants are chemicals that can potentially produce the most harmful effects on the environment and human health. Such an approach allows concentrating on the most hazardous chemicals and achieving the maximum possible results in raising ambient air quality [4, 13, 14, 23].

Uncertainties of the present study include possible inaccuracy and changeability of parameters of pollution sources; impossibility to consider simultaneous work of all these sources; inaccuracies in completeness of the systemic assessment of spatial-differentiated calculated exposure and health risks; gaps in the scientific theory of prediction based on cause-effect relations (model uncertainties).

Conclusions. A differentiated approach to selecting optimal regulatory actions involves identification of priority chemicals and objects for setting emission quotas considering their contributions to total ambient air pollution. It turned out to be relevant and precise in minimization of airborne health risks and provision of sanitary-epidemiological safety in all residential areas in the analyzed city. Approbation of the methodical approach fixed in the Methodical Guidelines MR 2.1.6.0320-23 with heat-power engineering objects used as an example demonstrates that it is eligible for ambient air quality management under local or total ambient air pollution created by emission sources, which are heterogeneous in their intensity and structure, located in close proximity to residential areas.

Our study results show that implementation of air protection measures and reductions by 18.1 thousand tons in the total emissions of more than 20 chemicals by heat-power engineering objects in accordance with the Complex Plan and considering their contributions to total ambient air pollution (between 1 and 99 % in different areas per different chemicals; contributions to health risks reach 37 %) will not significantly improve the living conditions for people residing in the analyzed areas. This is due to persisting violations of safety standards since peak chemical levels will remain 6.25 single MPL and 7.0 average annual MPL. In contrast to that, desirable improvement can be achieved by suggested optimal regulatory actions based on the differentiated approach to managing ambient air quality and health risks.

A differentiated reduction by 3.47 thousand tons in emissions from all heat-power engineering objects is optimal and sufficient considering contributions made by emission sources and specific chemicals to total ambient air pollution. This is 5.2 times lower than reductions stipulated by the Complex Plan for reductions in emissions. It is 2.69 thousand tons lower (16.8 % of the 2017 emissions) at the TPS-1; by 0.12 thousand tons at all ineffective coal-fueled boiler houses (1.1 %); by 0.65 thousand tons at autonomous heat supply sources (12.3 %). The following ten chemicals should be considered priority ones and mandatory for reduction at heat-power engineering objects in the analyzed city: nitrogen dioxide, carbon, sulfur dioxide, benzo(a)pyrene, particulate matter, carbon oxide, chromium, inorganic dust: 70–20 % SiO_2, up to 20 % SiO_2, and manganese. Reductions in their levels vary between 1 and 100 % and are determined individually for each object. To ensure compliance with the safety standards for chemical levels in ambient air and to achieve acceptable levels of health risks on the analyzed territory, it is necessary to achieve object-specific differentiated reductions in emissions not only from heat-power engineering objects but also from other emission sources (economic entities and motor transport) by 1.06 thousand tons overall. Implementation of the suggested optimal regulatory actions at heat-power engineering objects in the analyzed city considering their contributions will ensure compliance with safety standards and acceptable health risk levels in all residential areas and at all points used for setting quotas of emissions.

Use of a differentiated approach to selecting optimal regulatory actions as regards all sources of ambient air pollution will make it possible for decision-makers to define priority environmental protection activities, adjust the Complex plans on ambient air quality improvement, update regional urban development plans, and motivate the business community to implement effective measures aimed to reduce emissions of chemicals, which are priority ones as per health risk criteria. This will also support systemic interdepartmental interactions in order to provide sanitary-epidemiological wellbeing and environmental safety,

Funding. The research was not granted any sponsor support.

Competing interests. The authors declare no competing interests.

References

1. Kislitsyna V.V., Surzhikov D.V., Likontseva J.S., Golikov R.A., Pestereva D.V. Assessing Population Health Risks Posed by Air Pollution Related to Coal Mine Reclamation. *ZNiSO*, 2023, vol. 31, no. 6, pp. 54–62. DOI: 10.35627/2219-5238/2023-31-6-54-62 (in Russian).

2. Efimova N.V., Kuzmina M.V., Bobkova E.V. Assessment of the annual trend of chemical aerogenic risk to health and mortality of the population at an industrial center. *Gigiena i sanitariya*, 2023, vol. 102, no. 12, pp. 1375–1380. DOI: 10.47470/0016-9900-2023-102-12-1375-1380 (in Russian).

3. Putyatin D.P., Ovodkov M.V. Scientific and methodological support of the Federal project ‘Clean air’ and the experiment on emission quotas. *Okhrana okruzhayushchei sredy i zapovednoe delo*, 2022, no. 3, pp. 49–59 (in Russian).

4. Zaitseva N.V., May I.V., Kiryanov D.A., Goryaev D.V. Scientific substantiation of priority chemicals, objects for setting quotas and trends in mitigating airborne public health risks within activities performed by the sanitary service of the Russian Federation. *Health Risk Analysis*, 2022, no. 4, pp. 4–17. DOI: 10.21668/health.risk/2022.4.01.eng

5. Starova E.V. New legal instruments of limitation of atmospheric emissions. *Ekologicheskoe pravo*, 2020, no. 2, pp. 27–31. DOI: 10.18572/1812-3775-2020-2-27-31 (in Russian).

6. Prüss-Ustün A., Wolf J., Corvalan C., Neville T., Bos R., Neira M. Diseases due to unhealthy environmental: as updated estimate of the global burden of diseases attributable to environmental determinants of health. *J. Public Health (Oxf.)*, 2017, vol. 39, no. 3, pp. 464–475. DOI: 10.1093/pubmed/fdw085

7. Komarova A.V., Maklakova E.A. Emission quotas on the territory of the Russian Federation. *Materialy Vserossiiskoi molodezhnoi konferentsii, posvyashchennoi Mezhdunarodnomu dnyu Zemli: sbornik trudov konferentsii*, Voronezh, 2022, pp. 53–59. DOI: 10.34220/IED2022_53-59 (in Russian).

8. Gurvich V.B., Kozlovskikh D.N., Vlasov I.A., Chistyakova I.V., Yarushin S.V., Kornilkov A.S., Kuzmin D.V., Malykh O.L. [et al.]. Methodological approaches to optimizing ambient air quality monitoring programs within the framework of the Federal Clean Air Project (on the example of Nizhny Tagil). *ZNiSO*, 2020, no. 9 (330), pp. 38–47. DOI: 10.35627/2219-5238/2020-330-9-38-47 (in Russian).

9. Revich B.A. Natsional'nyi proekt «Chistyi vozdukh» v kontekste okhrany zdorov'ya naseleniya [Clean Air National project in the context of population health protection]. *Ekologicheskii vestnik Rossii*, 2019, no. 4, pp. 64–69. Available at: http://ecovestnik.ru/index.php/2013-07-07-02-13-50/nashi-publikacii/3132-natsionalnyj-proekt-chistyj-vozdukh-v-kontekste-okhrany-zdorovya-naseleniya (March 01, 2024) (in Russian).

10. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. Geneva, WHO, 2016, 147 p.

11. Gosman D.A., Romanchenko M.P., Sabadash O.V. Vliyanie zagryazneniya atmosfernogo vozdukha goroda Donetska tyazhelymi metallami na zabolevaemost' naseleniya [Influence of ambient air pollution with heavy metals in Donetsk on population incidence]. *Donetskie chteniya 2020: obrazovanie, nauka, innovatsii, kul'tura i vyzovy sovremennosti: Materialy V Mezhdunarodnoi nauchnoi konferentsii*. In: S.V. Bespalova ed., 2020, pp. 180–182 (in Russian).

12. Chetverkina K.V. Otsenka nekantserogennogo riska dlya zdorov'ya naseleniya, obuslovlennogo ingalyatsionnym postupleniem pollyutantov iz atmosfernogo vozdukha, v ramkakh realizatsii federal'nogo proekta «Chistyi vozdukh» (na primere g. Bratska, Krasnoyarska, Noril'ska, Chity) [Assessment of non-carcinogenic population health risk caused by inhaling pollutants from ambient air within the framework of the Federal project ‘Clean Air’ (using the example of Bratsk, Krasnoyarsk, Norilsk, Chita)]. *Analiz riska zdorov'yu – 2020 sovmestno s mezhdunarodnoi vstrechei po okruzhayushchei srede i zdorov'yu Rise-2020 i kruglym stolom po bezopasnosti pitaniya: Materialy X Vserossiiskoi nauchno-prakticheskoi konferentsii s mezhdunarodnym uchastiem: in 2 volumes*. In: A.Yu. Popova, N.V. Zaitseva eds., 2020, vol. 2, pp. 268–272 (in Russian).

13. Danilkina V.G., Prusakov V.M., Filippova T.M., Selivanova N.V. Opredelenie prioritetnykh vrednykh veshchestv promyshlennykh vybrosov po kriteriyam analiza riska zdorov'yu naseleniya [Determination of priority harmful substances from industrial emissions based on population health risk analysis criteria]. *Sovremennye tendentsii razvitiya nauki i tekhnologii*, 2016, no. 3–2, pp. 21–24 (in Russian).

14. Khamidulina Kh.Kh., Rabikova D.N., Petrova E.S., Guseva E.A. Podkhody k opredeleniyu prioritetnykh khimicheskikh veshchestv dlya gosudarstvennogo regulirovaniya [Approaches to identifying priority chemicals for government regulation]. *Zdorov'e i okruzhayushchaya sreda: sbornik materialov mezhdunarodnoi nauchno-prakticheskoi konferentsii*. In: N.P. Zhukova ed., Minsk, 2019, pp. 412 (in Russian).

15. Economic cost of the health impact of air pollution in Europe: clean air, health and wealth. Copenhagen, WHO Regional Office for Europe, OECD, 2015, 66 p.

16. Oganyan N.G. Measurement uncertainty and corresponding risk of false decisions. *J. Phys. Conf. Ser.*, 2019, vol. 1420, pp. 012003. DOI: 10.1088/1742-6596/1420/1/012003

17. Gorbanev S.A., Markova O.L., Yeremin G.B., Mozzhukhina N.A., Kopytenkova O.I., Karelin A.O. Features of hygienic assessment of atmospheric air quality in the area of the location of the enterprise for the production of mineral fertilizers. *Gigiena i sanitariya*, 2021, vol. 100, no. 8, pp. 755–761. DOI: 10.47470/0016-9900-2021-100-8-755-761 (in Russian).

18. Klyuev N.N., Yakovenko L.M. 'Dirty' cities in Russia: factors determining air pollution. *Vestnik Rossiiskogo universiteta druzhby narodov. Seriya: Ekologiya i bezopasnost' zhiznedeyatel'nosti*, 2018, vol. 26, no. 2, pp. 237–250. DOI: 10.22363/2313-2310-2018-26-2-237-250 (in Russian).

19. Mai I.V., Zagorodnov S.Yu., Max A.A. Fractional and component composition of dust in the air of workplace at machinery enterprise. *Meditsina truda i promyshlennaya ekologiya*, 2012, no. 12, pp. 12–15 (in Russian).

20. Khludeneva N.I. Emission Quotas as a Way to Reduce the Negative Impact on Atmospheric Air: Problems of Implementing an Experimental Legal Regime. *Zakon*, 2023, vol. 20, no. 10, pp. 39–46. DOI: 10.37239/0869-4400-2023-20-10-39-46 (in Russian).

21. Zaitseva N.V., Kleyn S.V., Goryaev D.V., Andrishunas A.M., Balashov S.Yu., Zagorodnov S.Yu. Effectiveness of complex plans for air protection activities at heat and power enterprises as per risk mitigation and health harm indicators. *Health Risk Analysis*, 2023, no. 2, pp. 42–57. DOI: 10.21668/health.risk/2023.2.04.eng

22. Kuz'min S.V., Kuchma V.R., Rakitskii V.N., Sinitsyna O.O., Shirokova O.V. O nauchnom obosnovanii natsional'noi sistemy obespecheniya sanitarno-epidemiologicheskogo blagopoluchiya, upravleniya riskami zdorov'yu i povysheniya kachestva zhizni naseleniya Rossii [On the scientific substantiation of the national system for ensuring sanitary and epidemiological well-being, managing health risks and improving the quality of life of the population of Russia]. *Razvivaya vekovye traditsii, obespechivaya «Sanitarnyi shchit» strany: Materialy XIII Vserossiiskogo s"ezda gigienistov, toksikologov i sanitarnykh vrachei s mezhdunarodnym uchastiem, posvyashchennogo 100-letiyu osnovaniya Gosudarstvennoi sanitarno-epidemiologicheskoi sluzhby Rossii*. In: A.Yu. Popova, S.V. Kuz'min eds., Mytishchi, 2022, pp. 6–9 (in Russian).

23. Kuzmin S.V., Avaliani S.L., Dodina N.S., Shashina T.A., Kislitsin V.A., Sinitsyna O.O. The practice of applying health risk assessment in the Federal Project "Clean Air" in the participating cities (Cherepovets, Lipetsk, Omsk, Novokuznetsk): problems and prospects. *Gigiena i sanitariya*, 2021, vol. 100, no. 9, pp. 890–896. DOI: 10.47470/0016-9900-2021-100-9-890-896 (in Russian).

24. Revich B.A. How effective is 'Clean air' project for health in 12 cities? *Ekologicheskii vestnik Rossii*, 2020, no. 3, pp. 58–68 (in Russian).

Zaitseva N.V., Kleyn S.V., Kiryanov D.A., Andrishunas A.M., Chigvintsev V.M., Balashov S.Yu. Optimization of regulatory actions based on a differentiated approach to managing ambient air quality and health risks. Health Risk Analysis, 2024, no. 1, pp. 4–17. DOI: 10.21668/health.risk/2024.1.01.eng

Received: 29.02.2024
Approved: 21.03.2024
Accepted for publication: 25.03.2024