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METHODICAL APPROACHES TO SELECTING OBSERVATION POINTS AND PROGRAMS FOR OBSERVATION OVER AMBIENT AIR QUALITY WITHIN SOCIAL AND HYGIENIC MONITORING AND "PURE AIR" FEDERAL PROJECT

N.V. Zaitseva[1], I.V. May[1], S.V. Kleyn[1], D.V. Goryaev[2]

[1]Federal Scientific Center for Medical and Preventive Health Risk Management Technologies, 82 Monastyrskaya str., Perm, 614004, Russian Federation
[2]Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, Krasnoyarsk Region office, 21 Karatanova Str., Krasnoyarsk, 660049, Russian Federation

The Federal project entitled "Pure air" is a part of "Ecology", the National project; its primary goal is to achieve a significant improvement in ambient air quality in cities where at present air contamination and population health risks related to it are the most significant. Activities aimed at improving the ecological situation in these cities are provided with the considerable state investment. Results of systemic instrumental measuring that is performed within state systems of ecological and social-hygienic monitoring are considered to be the most informative and reliable database to assess efficiency of air-protecting activities accomplished within the project. Our research goal was to develop and test methodical approaches to substantiating points and programs for observation over ambient air quality within social-hygienic monitoring. The said approaches were to be tested on concrete examples taking into account the existing ecologic monitoring system. We chose the following objects to test our approaches: two cities out of the priority list, namely Krasnoyarsk and Chita. Systemic observations are performed in both cities. There are data on the structure of emissions from all major contamination sources. In Krasnoyarsk there is an aggregated database that contains data on parameters of emission sources; there was no such database in Chita at the moment our research was accomplished. Given the availability of necessary initial data, we suggested algorithms for creating a system of points where observation posts were to be located and for monitoring programs development. We applied health hazards and health risks as our basic criterion for creating an observation system within social-hygienic monitoring. It was shown that data that were collected at ecologic monitoring posts without any changes in their location could be applied to solve tasks related to assessing and predicting health risks as well as analyzing efficiency of accomplished activities provided that research programs were supplemented with parameters that were priority ones as per health hazards and risks. We developed approaches to selecting points and programs for independent research within social-hygienic monitoring. These approaches involve dividing city territories into specific zones as per potential health hazards (when dispersal is not calculated) or health risk levels (when dispersal is calculated); substantiating a list of priority admixtures taking into account carcinogenic and/or non-carcinogenic hazards and risks as well as results of accomplished instrumental measuring and determining parameters of marker (indicator) enterprises with their emissions making the most significant contribution into air contamination.

Key words: *ambient air quality, social-hygienic monitoring, observation posts and programs, health risk.*

Air quality in industrial cities should necessarily conform to hygienic standards; achieving it has been a most significant social, ecological, and sanitary-hygienic task for many years all over the world, including the Russian Federation [1–6].

The Federal project "Clean air" which is a part of the National project "Ecology" outlines

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

Irina V. May – Doctor of Biological Sciences, Professor, Deputy Director responsible for research work (e-mail: may@fcrisk.ru; tel.: +7 (342) 237-25-47; ORCID: https://orcid.org/0000-0003-0976-7016).

Svetlana V. Kleyn – Doctor of Medical Science, head of the department of methods for sanitary analysis and monitoring (e-mail: kleyn@fcrisk.ru; tel.: +7 (342) 236-32-64; ORCID: https://orcid.org/0000-0002-2534-5713).

Dmitrii V. Goryaev – Candidate of Medical Sciences, Head of the Administration of the Federal Service on Surveillance for Consumer rights protection and human well-being in Krasnoyarsk region (e-mail: goryaev_dv@24.rospotrebnadzor.ru; tel.: +7(391) 226-89-50; ORCID: http://orcid.org/0000-0001-6450-4599).

priority territories where air contamination and potential population health risks are an acute problem[1]. These territories are to become research objects where approaches to optimal planning and implementation of air-protecting activities are to be tested; ecological situation is to improve significantly; threats to population health and life that are related to aerogenic environmental factors are to be minimized. Should these approaches be considered efficient, they can be applied in other regions in the country and in long-term planning as well.

The Federal project "Clean air" is aimed at overall 20 % decrease in gross emissions on priority territories. Undoubtedly, this value is in line with potential improvements in ecological and sanitary-epidemiological situation. But still, actual air quality improvement on a specific territory depends not only on a decrease in emission masses but also on spatial location of emission sources, housing, recreational, and other standardized zones, as well as on emission parameters (height, temperature, linear velocity, etc.). Component structure of emissions that are to be reduced is also extremely important.

Instrumental measurements performed within ecological monitoring, social and hygienic monitoring, and industrial control by economic entities themselves provide the most informative and reliable data for assessing efficiency of air-protecting activities accomplished within the project. Each of the above-mentioned monitoring types has its own tasks and procedures for selecting monitoring points and programs. Thus, ecologic monitoring primarily aims at observing over air pollution caused by economic activities and meteorological conditions and at predicting expected changes in air quality over a long-term period[2]. Industrial control is to register whether an economic entity conforms to fixed safety requirements when performing its economic activities or violates them [7, 8]. And only social and hygienic monitoring (SHM) has a primary goal that is to assess population health, detect any changes in it, and to predict a future situation under exposure to environmental factors[3]. That is, it focuses not on a simple concentration of this or that contaminant (admixture or substance) in the air but on a health parameter related to it.

Given that, air quality assessments within SHM should be oriented at those admixtures that are potentially the most hazardous for human life and health under short-term and/or long-term exposure; are registered in the air on a territory where population reside permanently; create risks that adverse effects on health can summate or enhance (become synergic) under simultaneous exposure to them combined with a whole set of any other admixtures [9–11]. The latter is especially significant for cities with developed industries due to a great list of substances contained in dust and gas air mixtures. Thus, for example, emissions from enterprises located in Nizhnekamsk (Republic of Tatarstan) contain approximately 320 specific substances and groups of admixtures; about 70, in Norilsk (Krasnoyarsk region); more than 60 admixtures, in Gubakha (Perm region); etc. It is also rather difficult to select sampling points as they should be representative taking into account city territories being large and significant number of population living under different exposure.

Therefore, selecting an optimal list of parameters to be measured and places to locate sampling points becomes a serious scientific task.

We should note that the state ecological monitoring system was created as far back as in the 60ties last century and it has a unified clear procedure that determines locations and number of monitoring stations as well as monitoring programs and periods. The procedure is fixed in the "Guide on control over air pollution"[4] and is obeyed by all the structural divisions of the authorized federal body, Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Rosgidromet). According to recommendations fixed by the said document (see section 2.2. "Location and number of monitoring

[1] The National project "Ecology" profile (approved by the RF Presidential Council on strategic development and national projects, the report dated December 24, 2018 No. 16). Available at: http://www.consultant.ru/document/cons_doc_LAW_316096/ (date of visit August 12, 2019).

[2] See section 1 in Guide P 52.04.186-89. Guide on control over air pollution. Moscow, 1991, 693 p.

[3] On sanitary-epidemiologic welfare of the population: the Federal Law issued on March 30, 1999 NO. 52-FZ (last edited on July 26, 2019). – Clause 45.Social and hygienic monitoring. Available at: http://www.consultant.ru/document/cons_doc_LAW_22481 (date of visit June 14, 2019).

[4] See sections 2.2-2.4 P 52.04.186-89. Guide on control over air pollution. Moscow, 1991, 693 p.

stations") "*…stations should be primarily located on housing territories where the most significant pollution can be expected, then, they should be located in an administrative center of a settlement, and on housing territories with different types of housing located there, as well as in parks and recreation zones…*". Monitoring programs should include admixtures selected as per air consumption (AC) criteria (see section 2.4 "Determining a list of admixtures that are subject to control") taking into account a hazard category this or that substance may belong to. It is obligatory to determine prevailing and the most widely spread admixtures, namely dust, sulfur dioxide, carbon oxide, and nitrogen dioxide, at basic stations for ecological monitoring. Programs are assumed to provide not less than 200 observations over concentration of each admixture.

A choice on points at which instrumental research is to be accomplished within industrial control is determined by a boundary of a sanitary protection zone and/or the closest housing territory [12–14].

Any unified and clear procedures for selecting monitoring points and creating monitoring programs for air quality control are not fixed within SHM. There is a letter of guidance issued in 2006[5] that determines basic principles for selecting measurement points and these instructions are similar to that given by the Federal Service for Hydrometeorology and Environmental Monitoring of Russia: "*…stationary or mobile stations are to be located in places selected on the basis of preliminary examination of ambient air pollution in a settlement with industrial emissions, emissions from motor transport, from communal and other sources and conditions of their dispersion. Stationary and mobile stations are to be located on housing territories with different types of housing … Location of stations is to be determined taking into account the highest population density and number… location of industrial zones, streets, and motorways… necessary data should be collected and databases created in order to estimate priority contaminants…*". Unfortunately, this letter of guidance doesn't give any recommendations on what should be included into preliminary research, or what data should be taken as grounds for assessing priorities.

Yet many researchers are trying to solve tasks related to scientific foundation for points and programs of monitoring over air quality. Since automated programs for calculating emission dispersion were introduced, spatial analysis of concentration fields has become one of the most significant tools for improving a system for selecting monitoring points and admixtures to be controlled [15, 16]. Dispersion results have become even more relevant since geoinformation systems were implemented into practice [17, 18]. However in some authors' opinion, dispersion calculations require validation of their results with data obtained from automated systems that provide uninterrupted control over emissions and/or instrumental research [19]; they can't be considered a single foundation for creating monitoring programs [20]. Health risk assessment methodology for assessing risks caused by exposure to chemicals that pollute the environment now covers such safety criteria as reference levels under short-term and chronic exposure, and it has resulted in understanding that monitoring programs can and should be developed taking into account potential threats for people [20–22]. And a mechanism aimed at selecting priorities in this case should be more complicated than a simple calculation of air consumption.

Having realized how complicated this problem was, a lot of researchers now believe it is vital to integrate various monitoring systems. Thus, Roslyakov et al. [23, 24] outlined certain approaches to combining results of industrial automated control over emissions from a thermal power station (TPS) with results obtained via monitoring over ambient air quality in a zone influenced by an emission source and calculated dispersion of emissions from TPS chimney. Darenskikh (2018) pointed out it was vital to create a unified complex approach when organizing state surveillance and industrial control related to ambient air protection [25]. Ochinnikova et al. (2018) stated it was necessary to combine social and hygienic monitoring and sanitary-epidemiologic control in the sphere of ambient air

[5] On organizing laboratory control within social and hygienic monitoring activities: The Letter by the Federal Service for Surveillance over Consumer Rights Protection and Human Well-being dated October 01, 2006 No. 0100/10460-06-32. Available at: http://50.rospotrebnadzor.ru/293/-/asset_publisher/U8Fg/content/письмо-от-02-10-2006-№-0100-10460-06-32 (date of visit August 01, 2019).

protection [26]. A monograph issued and edited by G.G. Onishchenko contained certain postulates on how to combine ecological monitoring and social and hygienic monitoring systems [27].

However, normative and methodological foundation for such integration is rather scarce at the moment. Yet, all the tasks formulated within the federal project require such integration and create preconditions for its implementation on priority territories.

Our research goal was to suggest and test approaches to substantiating points and programs for monitoring over ambient air quality on concrete examples within social and hygienic monitoring activities taking into account existing ecological monitoring networks.

Data and methods. We chose two cities out of priority ones as our research objects; they were Krasnoyarsk and Chita, cities with different population, industries, and emissions structure but quite similar in terms of climatic and geographic conditions and poor sanitary-epidemiologic situations as per ambient air quality. Both territories are located in zones where the stable high-level Siberian anticyclone is localized; this anticyclone creates down flows that prevent pollutants from dispersing. There are few precipitations on both territories that can clean the atmosphere; heating season is long; energy is provided mostly by coal and boiler-oil and coal is predominantly high-ash brown one; both territories specialize in extracting and heavy industries [28].

1.09 thousand people live in Krasnoyarsk, and its area is equal to 353.9 km^2. Major industries are metallurgy, machine building, metal processing, chemical industry, construction materials production etc. Gross emission into the atmosphere amounts to approximately 145 thousand tons per year. There are more than 270 chemicals (or summarily controlled groups of substances) in the admixtures list for the city. 19 admixtures are monitored at 8 stationary monitoring stations belonging to Rosgidromet' Regional Office for Hydrometeorology and Environmental Monitoring; approximately 25 admixtures are monitored at 11 mobile stations within SHM system (admixtures lists can be different in different years). There are 5 monitoring stations within the regional monitoring system (21 admixtures under control). Economic entities in the city perform industrial control at 31 points[6]. Single and/or average daily MPCs in the city that are higher than hygienic standards are detected for the following admixtures: dusts, sulfur oxide, nitrogen dioxide, hydrofluoride, chlorides, etc. In 2018 in Krasnoyarsk there were 23 registered cases of benzpyrene concentrations in the air that were higher than 10 MPC av.d. Air pollution index was considered to be very high as per criteria fixed by Rosgidromet (complex air pollution index IZA5>14).

Population in Chita is approximately 350 thousand and the city area is 534 km^2; its major industries are energy production, machine building, construction materials production, and food industry. This city is a large railroad junction. Total emissions into the atmosphere amount to approximately 53-60 thousand tons per year. 5 stationary monitoring stations that belong to the state Rosgidromet system perform systematic monitoring over 12 admixtures and register cases in which hygienic standards are violated as per concentrations of particulate matter (dust), hydrogen sulphide, and benzpyrene (up to 10 MPC and higher).

There is a combined database on parameters of emission sources created in Krasnoyarsk; it includes emission sources related to households that don't have central heating and emissions from motor transport. There was no similar database in Chita at the moment our approaches were being developed. We considered these two territories to be test platforms where our approaches could be tested given different volumes of available initial data.

We used data and materials created in the regions by experts who had to substantiate complex plans aimed at reducing emissions of pollutants into the ambient air; we also took data provided by regional Rospotrebnadzor offices in Krasnoyarsk region and Transbaikalia region.

We analyzed data on actual emissions from industrial enterprises in Krasnoyarsk and Chita over 2014-2018 (statistical reports named "2-TP Air" for industrial enterprises), and data

[6] On ecological situation and environmental protection in Krasnoyarsk region in 2018: The State report. Available at: http://mpr.krskstate.ru/dat/File/3/svodnyuidoklad.pdf (date of visit August 01, 2019).

on traffic intensity on major transport highways in the cities. We examined data on average annual concentrations of each admixture at each monitoring station, maximum single concentrations and single concentrations taken at 95%-frequency irrespective of a station belonging to this or that monitoring authority.

As regards results of combined calculation for a city as a whole, we took only those of them that were performed according to standardized procedures and unified software ("Ecolog" or "Ecolog-gorod" unified programs for air pollution calculation). Our procedure involved applying vector maps of the examined territories (we used ARCGIS 9.3.1 geoinformation system); each map had specific subject layers for housing areas, roads and streets, and industrial grounds. All monitoring points were given a geocode and put on relevant maps.

We took publicly available data on meteorological parameters, including average annual wind rose, that were typical for the examined territories[7].

When creating our approaches, we adhered to an opinion that results of instrumental research on ambient air quality should provide a possibility to solve basic tasks that were given to the social and hygienic monitoring system at the moment[8] including:

– information support for hygienic assessment (diagnostics) of the environment;

– revealing cause and effect relations between population health and exposure to environmental factors basing on system analysis and health risk assessment;

– working out recommendations on necessary actions aimed at eliminating detected adverse effects produced by environmental factors;

– detecting risk indicators implying that obligatory requirements can be violated; such indicators are usually revealed during control procedures without any interaction with juridical persons or private entrepreneurs[9].

We were guided by WHO postulates on how to solve tasks related to hygienic assessment, including risk assessment; some recommendations were given on locating sampling points (monitoring stations) both in housing areas with the highest contamination and in zones with the most typical concentrations of admixtures in the air (average for a city). Revealing cause and effect relations requires additional points located in zones with the lowest concentrations as data collected at such points are necessary for correct building of models for "concentrations (dose) – response (effect)" correlations [29, 30]. Tasks related to substantiating and assessing efficiency of air-protecting activities and social and hygienic monitoring as control measures performed without any interactions with juridical persons or private entrepreneurs require monitoring points that are fully oriented at zones exposed to specific contamination sources where such activities take place.

Multi-dimensional tasks, expensive instrumental research, and limited personnel, financial, and other resources called for integration of all the systems for monitoring over air quality, including ecological monitoring, social and hygienic monitoring, and industrial control, population life and health remaining the top priority in the process. Dispersion calculations were treated as a component in the overall system for priority selection.

We assumed that a system for selecting monitoring points and programs should be dynamic; it should be revised and developed basing on both calculated data and research results obtained during a certain period.

Basic results. In case there are no results of consolidated calculations for a specific territory we suggest the following algorithm for substantiating selected points where monitoring stations and programs for monitoring over ambient air quality should be located.

1. The first task is to create a vector map of a city with industrial grounds, housing areas and all the existing points for monitoring over ambient air quality being put on it. Attribute database on industrial grounds should contain data on actual and permissible emissions of

[7] Open geodata catalogue. Available at: http://opengeodata.ru (date of visit August 10, 2019).

[8] On Approval of the Provisions on social and hygienic monitoring: The RF Government Order dated February 2, 2006 No. 60, Moscow. Available at: https://rg.ru/2006/02/17/monitoring-dok.html (date of visit August 10, 2019).

[9] On protecting rights of juridical persons and private entrepreneurs when state control (surveillance) and municipal control is performed: the Federal Law issued on December 26, 2008 No. 294-FL (last edited on August 02, 2019). – Clause 8.3. Available at: www.consultant.ru/document/cons_doc_LAW_83079 (date of visit August 05, 2019).

contaminants into the atmosphere. A layer with data on housing should have information on population density in various parts of a city.

2. All housing areas are to be covered with a regular grid. A pitch in this grid is to be determined by the overall area of an examined territory and computational capabilities of developers. When testing our approaches, we took grids with pitches equal to 200 x 200 m and 400 x 400 m. A thicker grid provides the most validated conclusions; however, a grid with its pitch being equal to 400 x 400 m also yielded satisfactory results that suited our analysis. A larger regular grid seems unadvisable as ground concentrations detected in zones influenced by low and average-high emissions sources tend to change considerably as a distance from a source grows and a large grid may fail to "capture" high concentrations of an admixture.

3. According to section 4.7. in Guide No. 2.1.10.1920–04 "Guide on assessing health risks under exposure to chemicals that pollute the environment" indexes showing comparative carcinogenic and non-carcinogenic hazards are to be calculated for each economic entity that is a source of pollutants-containing emissions; such calculations should be made for each substance.

3.1. Total index of carcinogenic (K_i^{K}) and non-carcinogenic ((K_i^{H}) hazard is calculated for an enterprise (an economic entity) as per the following formula (1)

$$K_i = \sum_{n=1}^{N} E_j \cdot TW_j, \qquad (1)$$

where

E_j is a conditional exposure to a j-th admixture, tons per year

TW_j is a weight coefficient for influence on health that is included into calculating carcinogenic or non-carcinogenic hazard quotients according to Tables 4.7. and 4.8. P 2.1.10.1920–04[10, 11].

T is a number of admixtures emitted by an economic entity.

3.2. Each enterprise is characterized with a quotient; this is a standardized "hazard" quotient (K_i) that takes into account both carcinogenic and non-carcinogenic hazard quotients.

$$K_i^{\text{H}} = \frac{K_i}{K^{\max}}, \; K_i^{\text{K}} = \frac{K_i}{K^{\max}}, \; K_i = K_i^{\text{H}} + K_i^{\text{K}}, \qquad (2)$$

where i is a number of an enterprise.

4. The geometric center of each industrial ground is linked to the central point of each square in an estimated grid with a straight line (vector L) (vectors are not designed when a point is located more than 20 km away from an economic entity).

5. Direction of each vector correlates with vectors in a wind rose. Each vector has its own quotient that characterizes repeatability of a wind in neighboring points of a wind rose. Vector direction is calculated as per the following formula (3):

$$V = \frac{(g - g_1)}{(g_2 - g_1)}(v_2 - v_1) - v_1, \qquad (3)$$

where g is wind direction, grades;

g_1, g_2 are vector directions in neighboring points, grades;

v_1, v_2 is repeatability of a wind in neighboring points.

The quotient is – $L_{im} = \frac{1}{R_{im}} V_{im}$,

where m is a number of a square in an estimated grid.

6. Each square in an estimated gird is characterized with total hazard quotient (S_j) that takes into account potential impacts exerted by economic entities located on a given territory:

$$S_m = \sum_i K_i \cdot L_{im}. \qquad (4)$$

7. It is necessary to assess whether locations of already existing monitoring stations are relevant to those of hazardous zones that can be found on a given territory and to chemical factors that create hazards in the said zones; existing monitoring programs should also be relevant to hazardous factors.

8. The next stage is working out recommendations on how to optimize a system of monitoring over ambient air quality; this system should be based on results of the analysis and take into account the following aspects:

[10] See section 4.7. Guide No. 2.1.10.1920-04 Guide on assessing health risks under exposure to chemicals that pollute the environment. The RF Public Healthcare Ministry, The Federal Center for State Sanitary and Epidemiologic Surveillance. Moscow, 2004, 143 p.

[11] We neglected population number taking into account that any enterprise could influence a city as a whole; weakening of any influence was taken into account via a vector showing remoteness of an object from a calculated cell in a grid.

– a monitoring points network should allow assessing risks for not less than 95% of population living on a given territory;

– this network should have optimal density and be distributed over a given territory allowing for instrumental research becoming less and less representative the greater is a distance form a monitoring point[12];

– a monitoring program should include all the admixtures that can potentially create unacceptable health risks or make a considerable contribution into them (from 10 to 100%);

– this program may include substances that are marker ones (indicators) for enterprises with maximum emissions and greatest hazards as per calculated criterion K_i.

The approach was tested on the example of Chita; the test results were as follows:

– potential hazards for the city population that occur due to emissions from industrial enterprises are not homogenous (Figure 1);

– monitoring stations that belong to Rosgidromet monitoring system can be considered an integral part of the total monitoring network without any changes in their location;

– there should be at least two additional monitroing points (in north-western and eastern parts of housing area, in squares numbered 925 and 434), and it is well-grounded taking into account health risks and consequent assessment whether activities performed within "Clean air" project are efficient or not.

– emissions that contain sulfur dioxide, dusts, nitrogen oxides, manganese compounds, carbon oxide, benzpyrene, soot, fluorides, and hydrocarbons are priority ones in terms of health risks caused by them (Table 1).

Practically all the priority admixtures, except from manganese, are covered by already existing monitoring programs. Manganese is recommended to be included as an additional component. Besides, it is recommended to measure not only a sum of dusts at all the monitoring stations but also fine-dispersed fractions PM10 and PM2.5 as they are the most hazardous for human health [31, 32].

In case there are some consolidated calculations of emissions dispersion for a city as a whole we can suggest the following algorithm for substantiating selected points where monitoring stations are to be located and programs for monitoring over ambient air quality.

1. The first step is to create a database where each estimated point on a given territory is characterized with aggregate concentrations of N ingredients. This database is a matrix built on a database containing output files with calculation results.

2. The next step is calculating carcinogenic and acute and chronic non-carcinogenic risks

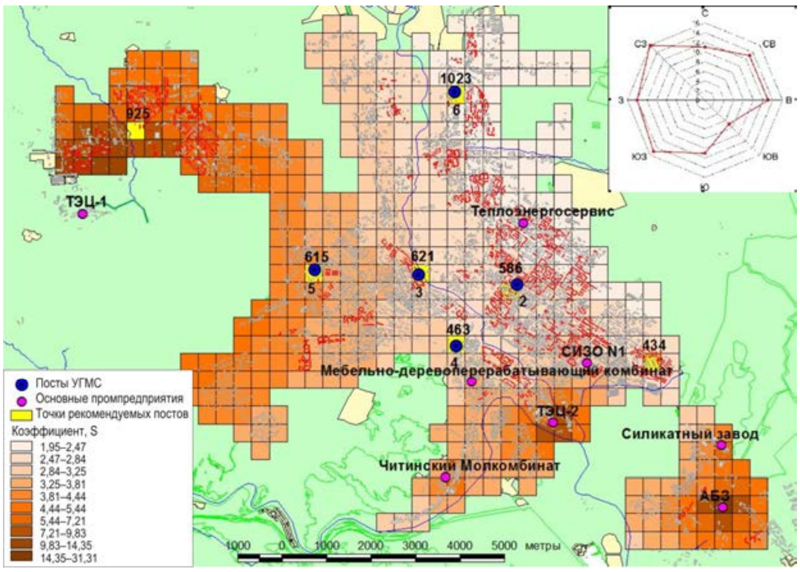

Figure 1. A map showing spatial distribution of comparative hazard index in Chita; hazards for population health are created by emissions from satitonary sources

[12] See section 3.4.2 Guide 52.04.186-89. Guide on control over air pollution. Moscow, 1991, 693 p.

Table 1

A fragment of a table that ranks admixtures as per their total hazards caused by all the chemical admixtures contained in emissions from industrial enetrprises located in Chita (as per data collected in 2018)

Chemical	Total hazard quotient of an admixture	
	Non-carcinogenic	Carcinogenic
Sulfur dioxide (Sulfury anhydride)	1,274,408.2	
Boiled oil ash (recalculated as per vanadium)	824,033.1	
Dust (as a sum of dusts with various chemical structure)	756,791.7	
Carbon (soot)	461,279.6	461,307.1
Nitrogen dioxide	457,863.2	
Nitrogen (II) oxide	75,592.5	
Manganese and its compounds	3,902.57	
Carbon oxide	2,397.23	
Dimethylbenzene (Xylene) (a mixture of o-, m-, and p-isomers)	1,026.51	
Benzpyrene (3,4-Benzpyrene)	220.00	22.0
White-spirit	40.58	
Poorly soluble fluorides	31.01	
Gaseous fluorides	18.68	
Saturated hydrocarbons C12-C19	18.49	
Sulfuric acid (as per H2SO4 molecule)	14.98	
Dihydrosulfide (Hydrogen sulfide)	3.73	
Formaldehyde	2.72	0.272

basing on all the obtained data; calculations are to be made for each estimated point in a grid according to conventional procedures[13]:

– hazard quotients for acute non-carcinogenic effects (HQac) calculated for priority chemicals that have scientifically grounded potential ability to exert acute negative influence on a human body; maximum single concentrations of examined chemicals are to be applied in this calculation;

– hazard quotients for chronic non-carcinogenic effects (HQcr) calculated for priority chemicals that have scientifically grounded potential ability to exert chronic negative influence on a human body; average annual concentrations of examined chemicals are to be applied in this calculation;

– individual carcinogenic risk (CR) for priority chemicals that have carcinogenic effects;

4. In order to divide a city territory into specific zones as per health risks, it is necessary to perform cluster analysis as per conventional procedures that allow dividing an examined selection of estimated points into clusters with "similar" parameters.

As parameters of carcinogenic and non-carcinogenic risks have different dimensions, it is necessary to standardize objects (parameters) prior to clusterization (5):

$$Y = \frac{X - \overline{X}}{S}, \qquad (5)$$

where

X is an initial vales of a parameter;

Y is a standardized value of a parameter;

$\overline{X}$ is an average value of a parameter;

S is a standard deviation.

5. When selecting a point where a station for monitoring over ambient air quality is to be located, the following requirements should be taken into account:

– a station in a selected zone (cluster) should be located at a point with the highest or typical parameters of a risk that occurs in a given zone,

– a station should be located in a zone with the highest density of exposed population.

In order to spot out a relevant point where a station for monitoring over ambient air quality is to be located within SHM system, a layer of clusters intersects with a layer that shows population

[13] Guide. 2.1.10.1920-04 Guide on assessing health risks under exposure to chemicals that pollute the environment. The RF Public Healthcare Ministry, The Federal Center for State Sanitary and Epidemiologic Surveillance. Moscow, 2004, 143 p.

density, the latter being a grid covering the overall housing area. As a result, each cell in a grid contains data on a number of population living on a given territory and parameters of occurring carcinogenic and non-carcinogenic risks. Due to layers intersection one can choose reference points within cluster boundaries where population density is higher than 75% of the maximum population density in a given cluster (>75% P^Nmax).

6. A list of contaminants that are to be measured at a selected point is determined via ranking health risk factors as well as with ranking tables taking into account material and normative resources available for a test laboratory.

We tested our approach on the example of Krasnoyarsk together with preliminary assessment of hazards caused by emissions as per the first algorithm.

The results were satisfactory similar as regards substantiating zones (points) where monitoring stations should be located. Monitoring stations network is sufficiently thick and it is advisable to only slightly relocate mobile stations used within a system of social and hygienic monitoring (Figure 2).

Priorities fixed as per potential hazards caused by admixtures (Table 2), results of dispersion calculation, and field observations results didn't coincide completely.

Thus, as per data on calculated dispersion in housing areas in the city (where monitoring stations are located) ground concentrations that were higher than MPC were detected for nitrogen dioxide (1.4 $MPS_{M.s.}$ and 3.9 $MPC_{av.d.}$), acrolein (up to 1.1 $MPS_{M.s.}$), non-organic dusts (up to 2.2 $MPS_{M.s.}$ at 0.06 $MPC_{av.d}$), hydrocarbons (up to 3 MPC). These data are partially confirmed by field observation results as nitrogen dioxide in concentrations higher than MPC is registered at many stations within Rosgidromet monitoring system and SHM system located in the region (1.1–1.9 $MPS_{M.s.}$; 1.1–1.8 $MPC_{av.d.}$). There were also excessive concentrations of particulate matter (up to 5 $MPS_{M.s.}$). Acrolein and hydrocarbons were not measured at monitoring stations and it is rather complicated to verify all the calculation results.

We detected substantial discrepancies between calculated and instrumental data as regards aromatic hydrocarbons: calculations performed on the basis of combined databases didn't reveal any "alarming" levels practically for any substance from this group (that is, there were no detected concentrations close to MPC or higher than it). But at the same time, there were excessive concentrations of certain chemicals measured at monitoring stations within Rosgidromet system; thus, benzene was detected in concentrations up to 5.2 MPC; xylene, up to 3.2 MPC; toluene, up to 1.5 MPC; ethylbenzene, up to 5 MPC. We also detected that hygienic standards were violated for such substances as fluorides (excessive concentrations detected at

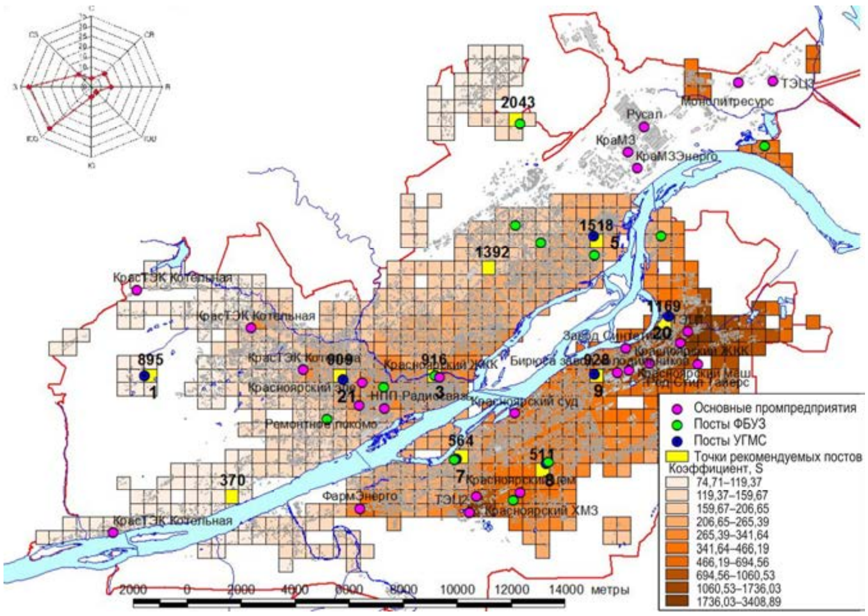

Figure 2. A map showing spatial distribution of comparative hazard index in Krasnoyarsk; hazards for population health are caused by emissions from stationary sources

Table 2

A fragment of a table that ranks admixtures as per their total hazards caused by all the chemical admixtures contained in emissions from industrial enetrprises located in Krasnoyarsk (as per data collected in 2018)

Chemical	Total hazard quotient of an admixture	
	Non-carcinogenic	Carcinogenic
Sulfur dioxide (Sulfury anhydride)	2,632,501.3	
Nitrogen dioxide (Nitrogen (IV) oxide)	1,893,227.7	
Dusts	1,854,052.3	
Gaseous fluorides	495,105.4	
Poorly soluble fluorides	410,583.1	
Nitrogen (II) oxide (Nitrogen oxide)	235,589.1	
Carbon (soot)	116,760.8	116,764.0
Benzpyrene (3,4-Benzpyrene)	113,814.7	11,381.5
Buta-1,3-dien (1,3-Butadien, divinyl)	95,961.1	95,961
Aluminum trioxide (recalculated as per aluminum)	68,480.8	
Chlorine	65,277.9	
Carbon oxide	54,542.9	
Epichlorohydrine	33,726.6	
Manganese and its compounds	28,133.4	
Prop-2-ennitrile (Acrylonitrile)	14,450.6	14,450.6
Chromium (Hexavalent chromium)	14,251.4	14,251.4
Copper oxide (recalculated as per copper)	10,025.1	
Hydrochloride acid	5,102.7	
Sulfuric acid (as per H2SO4 molecule)	4,404.6	
Xylene (mixture of o-, m-, p-isomers)	3,726.8	
Ammonia	2,773.2	
Vanadium (V) oxide	1,713.6	
Ethenylbenzene (Vinilbenzene, Styrene)	1,325.4	
Hydrogen cyanide	1,225.2	
Prop-2-en-1-al (Acrolein)	254.0	
Trichloroethylene	244.3	
1,2,4-Trimethylbenzene (Pseudocumene)	177.1	
Methylbenzene (Toluene)	138.8	
Saturated hydrocarbons C12-C19	127.3	
2-Chlorobutadien-1,3-dien (Chloroprene)	123.2	
Ethene (Ethylene)	100.0	
Lead and its non-organic compounds	70.7	0.707
Hydroxibenzene (Phenol)	64.2	
Butyl acetate	62.3	
Tetrachloroethylene (Perchloroethylene)	57.6	
Formaldehyde	42.0	4.197
Benzene	1.70	1.656

6 monitoring stations within Rosgidromet system out of 8); such concentrations were not predicted by dispersion calculations. That is, hazardous concentrations of fluorides can occur on a considerable part of the city area and exert negative influence on population health.

Calculated ground concentrations of such admixtures as metals (aluminum, copper, manganese, nickel, and cobalt) were equal to hundredths and thousandths of MPC and it allowed us to neglect them when creating monitoring programs, even taking into account health risks. In retrospect there were no monitoring, screening, or reconnaissance instrumental measurements of such admixtures performed on a territory. It was impossible to verify results of dispersion calculation.

Given that, we were guided by the following system of criteria when making recommendations on including an admixture (a substance) into a monitoring program:

– as per data collected via previous instrumental research, concentrations of an admixture that were higher than hygienic standards were registered directly at this monitoring point or at the closes monitoring station;

– as per results of combined dispersion calculations ground concentrations of a substance are predicted to be higher than MPC, but there have been no instrumental measurements of ground concentrations as regards this substance (admixture);

– as per data obtained via preliminary calculations of hazard quotients an admixture is among priority ones for a territory, but there have been no instrumental measurements of ground concentrations as regards this admixture;

– an admixture is an indicator (a marker one) for emissions from the largest enterprise on a territory, but there have been no instrumental measurements of ground concentrations as regards this substance (admixture);

– an admixture is detected in concentrations that allow predicting a substantial contribution into total carcinogenic or non-carcinogenic risk for population health as per data obtained via dispersion calculation or filed data.

Model recommendations on monitoring programs within SHM are given in Table 3.

We took into account a possibility that a program could be adjusted in future as per results of systematic examinations; for example, experts can exclude admixtures registered in concentrations that don't create unacceptable health risks, as well as admixtures that don't substantially increase health risks when they are combined with other substances with one-direction effects.

Conclusion. Our research proved that it was vital and well-timed to combined efforts taken by authorities and organizations that are responsible for assessing and managing ambient air quality on various territories. Should a combined monitoring network that includes both stationary and mobile stations of Rosgidromet, Rospotrebnadzor, and regional monitoring stations, be created, it would allow saving as many resources as possible and simultaneously create optimally thick and representative infrastructure for collecting data on actual ambient air quality. Measurement programs within existing Rosgidromet monitoring system that solves its own tasks could include admixtures that are priority ones as per health risks criteria. These measurements could be supplemented with examinations performed on the basis of monitoring networks within social and hygienic monitoring. Combined programs for sampling procedures and measurement techniques would allow taking into account all the data arrays both for Rosgidromet's and Rospotrebnadzor's authorities and organizations.

Data obtained via combined dispersion calculation at the moment should be treated as an additional information source that provides a better insight into specific spatial distribution of contamination. And here it seems to be ungrounded to rely only on calculation results due to substantial discrepancies between calculated data and field ones. But still, these detected discrepancies can give grounds for greater attention paid by surveillance authorities to certain economic entities and standards of permissible emissions fixed for them; they can also substantiate certain measures taken by control and surveillance authorities to identify contamination sources that are not included into combined databases and that are not taken into account when permissible exposure levels are fixed.

We have tested and suggested applying methodical approaches to substantiating points and programs for monitoring over ambient air quality within social and hygienic monitoring taking into account the existing ecological monitoring networks. At present these approaches can be implemented on any territory, both included into priority lists within the Federal project "Clean air" and those which are not in these lists. There is only one condition for their implementation to be efficient and it is decision-makers taking a genuine interest in receiving as complete and valid data on ambient air quality as it is only possible. These decision-makers should really be keen on providing safety and sanitary-epidemiologic welfare of the population.

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Table 3

Recommendations on a program for monitoring over ambient air quality within social and hygienic monitoring activities for Krasnoyarsk (a fragment)

	Criteria for an admixture to be included into a program
A mobile monitoring station belonging to Krasnoyarsk Regional Center for Hygiene and Epidemiology, Parkovaya str., 19. (coordinates: n.l. 56.02002 e.l. 092.97704)	
Chemical	Criteria for an admixture to be included into a program
Nitrogen (II) oxide	Concentrations deviate from hygienic standards Creates unacceptable acute and chronic health risks
Nitrogen dioxide	Concentrations deviate from hygienic standards Creates unacceptable acute and chronic health risks
Sulfur dioxide	Considerable contribution into chronic health risk (respiratory organs diseases, additional population mortality)
Carbon oxide	Considerable contribution into chronic health risk (cardiovascular system diseases, blood diseases)
Particulate matter (sum of dusts)	Considerable contribution into chronic health risk (respiratory organs diseases, cardiovascular system diseases, additional population mortality)
Particulate matter PM10	Considerable contribution into chronic health risk (respiratory organs diseases, cardiovascular system diseases, additional population mortality)
Particulate matter PM2,5	Considerable contribution into chronic health risk (respiratory organs diseases, cardiovascular system diseases, additional population mortality)
Ammonia	Considerable contribution into chronic health risk (respiratory organs diseases)
Fluorides	Considerable contribution into chronic health risk (respiratory organs diseases, musculoskeletal system diseases).
Formaldehyde	Considerable contribution into carcinogenic health risk
Benzpyrene	Concentrations deviate from hygienic standards. Considerable contribution into carcinogenic health risk
Dihydrosulphide	Examined within reconnaissance, makes a living environment uncomfortable
Acetaldehyde	Examined within reconnaissance. Carcinogen
Prop-2-en-1-al (Acrolein)	Potentially considerable contribution into health risk (respiratory organs diseases)
A mobile monitoring station belonging to Krasnoyarsk Regional Center for Hygiene and Epidemiology, Partizana Zheleznyaka str., 36 A (coordinates n.l. 56.03596 e.l. 92.92622)	
Nitrogen dioxide	Concentrations deviate from hygienic standards. Creates unacceptable acute and chronic health risks
Sulfur dioxide	Considerable contribution into chronic health risk (respiratory organs diseases, additional population mortality)
Carbon oxide	Considerable contribution into chronic health risk (cardiovascular system diseases, blood diseases)
Particulate matter (a sum of dusts)	Considerable contribution into chronic health risk (respiratory organs disease, cardiovascular system diseases, additional population mortality)
Particulate matter PM10	Considerable contribution into chronic health risk (respiratory organs diseases, cardiovascular system diseases, additional population mortality)
Particulate matter PM2,5	Considerable contribution into chronic health risk (respiratory organs diseases, cardiovascular system diseases, additional population mortality)
Benzpyrene	Concentrations are higher than MPC. Considerable contribution into carcinogenic health risk
Aluminum	A marker of emissions from a large air contamination sources. Potentially considerable contribution into chronic health risk (respiratory organs disease, central nervous system diseases, musculoskeletal system diseases)
Fluorides	Considerable contribution into chronic health risk (respiratory organs disease, musculoskeletal system diseases)
Nickel and its compounds	A marker of emissions from a large air contamination sources. Potentially considerable contribution into carcinogenic health risk
Cobalt	A marker of emissions from a large air contamination sources. Potentially considerable contribution into carcinogenic health risk
Acetaldehyde	Examined within reconnaissance. Carcinogen

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