

Selection of Priority Substances for Monitoring the Atmospheric Air Quality of Polluted Areas

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ABSTRACT

A study was carried out on the selection of priority substances for monitoring the quality of atmospheric air in Bratsk taking into account the criteria of risk to public health. Based on the results of the assessment of the parameters of the population health risk and the hygienic assessment of retrospective data, a list of 27 priority substances was determined. Optimization of the monitoring program, taking into account the list of priority substances, already at the first stages revealed the excess for 16 substances out of 27 substances recommended for air quality monitoring. Taking into account the spatial location of the existing air quality monitoring posts, monitoring covers 92.3 % of the entire population of Bratsk. The formation for the entire territory of Bratsk of consolidated databases on stationary and mobile sources of atmospheric pollution, followed by calculations of the dispersion of impurities, will make it possible to update and optimize the list of priority pollutants in the study area and propose points of the optimal location of posts for the task of monitoring the entire residential area of Bratsk

Keywords: atmospheric air, quality monitoring, comparative hazard index, hygienic assessment, health risk assessment, spatial assessment

1. INTRODUCTION

According to the World Health Organization, air pollution is one of the main health risk factors associated with the environment [1].

In the Russian Federation, the problem of atmospheric air pollution is very relevant for most regions of the country [2–5].

The Irkutsk Region is included in the list of priority subjects of the Russian Federation with the highest share of atmospheric air samples in urban settlements with an excess of hygienic standards for the content of pollutants; the share of non-standard samples in 2018 was 4.12 % [6].

The city of Bratsk is a large industrial center of Russia and the second largest city of the Irkutsk region, with a population of more than 200 thousand people (as of January 1, 2020, 226.269 thousand people) and an area of 42.8 thousand hectares. The main industries in the city are non-ferrous and ferrous metallurgy, pulp and paper and woodworking industries, fuel and energy complex, machine building, food industry [7].

In Bratsk, air pollution has been the highest in Russia for many years. This city is constantly included in the priority list of cities with the highest level of air pollution. According to the state monitoring data, the level of atmospheric air pollution is assessed as "very high", the main contribution to the formation of a high pollution index is made by such substances as benz(a)pyrene, carbon disulfide, formaldehyde, suspended solids, and hydrogen fluoride. More than 112 thousand tons of pollutants are

emitted into the air by industrial enterprises and vehicles annually [8].

Bratsk is one of 12 large industrial centers where the federal project "Clean Air" is being implemented [9]. The project plans to drastically reduce the level of air pollution in large industrial centers, including a reduction by at least 20 percent of the total volume of emissions of pollutants into the air in the most polluted cities.

To reduce the level of atmospheric air pollution, it is urgent to determine the list of priority chemicals that pollute the atmospheric air of Bratsk for monitoring tasks using instrumental methods.

Purpose of the study. Selection of priority substances for monitoring the atmospheric air of the study area (Bratsk), taking into account the criteria of risk to public health.

2. METHODS AND MATERIALS

The research was carried out in two stages. At the first stage of the study, information on gross emissions of pollutants from enterprises carrying out economic activities in the city of Bratsk was processed.

The list of chemicals to be included in the programs of in situ monitoring of atmospheric air quality was formed on the basis of the results of calculating the indices of comparative carcinogenic and non-carcinogenic hazard for 71 pollutants emitted by industrial enterprises in Bratsk.

Taking into account the data obtained, proposals were made to include pollutants with high indices of

comparative carcinogenic/non-carcinogenic hazard in the program for monitoring the quality of atmospheric air in Bratsk.

At the second stage of the study, a hygienic assessment of the results of instrumental studies of the quality of atmospheric air in Bratsk was carried out for compliance with hygienic standards (the maximum permissible maximum one-time concentration of chemicals in the air of populated areas (MPC_{mot}) and the maximum permissible average daily concentration of chemicals in the air of populated areas (MPC_{ad}) and public health risk criteria (HQ hazard ratios).

A hygienic assessment of the results of instrumental studies of the quality of atmospheric air in Bratsk was carried out using retrospective data from monitoring the quality of atmospheric air for 2014–2019 and after the optimization of the monitoring program, taking into account the list of priority substances for the period from January to May 2020. A hygienic assessment of the results of instrumental studies of atmospheric air quality in Bratsk was carried out according to the Bratsk Center for Hydrometeorology and Environmental Monitoring (Bratsk CHEM) and the Branch of the Federal Budgetary Institution of Health “Center for Hygiene and Epidemiology in the Irkutsk Region” in the city of Bratsk and Bratsk District.

Bratsk CHEM in 2014–2018 conducted observations at 5–6 stationary posts. The atmospheric air was monitored for the content of 19 pollutants: nitrogen dioxide, nitrogen oxide, benz(a)pyrene, suspended solids, methyl mercaptan, sulfur dioxide, hydrogen sulfide, carbon disulfide, heavy metals (iron, manganese, copper, nickel, lead, chromium, zinc), carbon oxide, formaldehyde, poorly soluble inorganic fluorides, gaseous fluoride compounds. In total, over 2014–2018, 138.631 thousand atmospheric air samples were taken and analyzed at the observation posts of the Bratsk Central Hydrometeorological Service.

In the city of Bratsk, the Branch of the Federal Budgetary Institution of Healthcare “Center for Hygiene and Epidemiology in the Irkutsk Region” in the city of Bratsk and the Bratsk District in 2014–2019 atmospheric air samples were taken and analyzed at 2–3 observation points for the content of 25 pollutants: nitrogen dioxide, aluminum and its compounds, benz(a)pyrene, benzene, suspended solids, dihydrosulfide, dimethyl disulfide, xylenes, manganese, methanol, methyl mercaptan, nickel, lead, sulfur dioxide, carbon disulfide, turpentine, toluene, carbon oxide, phenol, formaldehyde, poorly soluble inorganic fluorides, gaseous fluorides, chlorine, chromium 6+, ethylbenzene. During the study period (2014–2019), 11.605 thousand atmospheric air samples were taken in Bratsk.

The indices of the comparative hazard of chemicals were calculated in accordance with R 2.1.10.1920-04 “Guidelines for assessing the risk to public health when exposed to chemicals that pollute the environment” using the method of ranking chemicals (section 4.7.) [10].

The concentrations obtained as a result of instrumental studies of the quality of atmospheric air in Bratsk were assessed for compliance with hygienic standards [11] and

criteria for an acceptable risk to public health when exposed to chemicals [10]. Proposals for the formation of a list of priority substances, the share of air quality monitoring was formed taking into account the comparative hazard indices and the results of hygienic assessment.

3. RESULTS

As a result of the implementation of the first stage of the work, the total comparative hazard indices were obtained for 71 substances emitted by stationary sources of industrial enterprises in Bratsk. The value of the non-carcinogenic hazard index (HRI) for the analyzed substances varied in the range from 0.01 to 1662023.22. The carcinogenic hazard index (HRI_c) ranged from 11.17 to 2803.14 for such substances as benz(a)pyrene, benzene, carbon, ethylbenzene.

Based on the results of the assessment of the comparative hazard index, a preliminary list of 21 priority substances was formed in the Bratsk air quality monitoring program, which includes substances with a non-carcinogenic hazard index of more than 1000 and all substances with a carcinogenic effect: nitrogen dioxide, nitrogen oxide, aluminum and its compounds, benz(a)pyrene, benzene, suspended solids, hydrogen chloride, dihydrosulfide, dimethyl sulfide, methyl mercaptan, sulfur dioxide, sulfuric acid, turpentine, toluene, carbon, carbon oxide, phenol, poorly soluble inorganic fluorides, gaseous fluorides, chlorine, ethylbenzene.

A hygienic assessment of the results of instrumental studies of the quality of atmospheric air in Bratsk, carried out at the second stage of the work, showed that, according to retrospective data of monitoring of atmospheric air, the excess of hygienic standards in the period 2014–2019. were registered for 14 substances: nitrogen dioxide (up to 7.0 MPC_{mot}, up to 1.1 MPC_{ad}), aluminum and its compounds (up to 2.0 MPC_{ad}), benz(a)pyrene (up to 9.0 MPC_{ad}), benzene (up to 1.8 MPC_{mot}), suspended solids (up to 34.8 MPC_{mot}, up to 2.7 MPC_{mot}), dihydrosulfide (up to 2.1 MPC_{mot}), xylene (up to 2.7 MPC_{mot}), methyl mercaptan (up to 2.3 MPC_{mot}), carbon disulfide (up to 4.7 MPC_{mot}, up to 4.8 MPC_{mot}), carbon oxide (up to 5.8 MPC_{mot}), phenol (up to 9.5 MPC_{mot}, up to 1.6 MPC_{mot}), formaldehyde (up to 3.8 MPC_{mot}, up to 1.5 MPC_{ad}), gaseous fluoride compounds (up to 7.0 MPC_{mot}, up to 2.5 MPC_{ad}), ethylbenzene (up to 9.6 MPC_{mot}).

An assessment of the carcinogenic risk to the health of the population of Bratsk showed that under conditions of inhalation exposure to the test substances, the carcinogenic risk exceeded the upper limit of the acceptable risk level for the population (CR 10⁻⁴) in relation to formaldehyde (up to 1.03×10⁻⁴ for the child population, up to 1.10×10⁻⁴ for the adult population). The total individual carcinogenic health risk exceeded the acceptable level for both children and adults: TCR up to 1.52×10⁻⁴ and up to 1.63×10⁻⁴,

respectively. The main contribution to the unacceptable amount of carcinogenic risk was made by formaldehyde (up to 80.26 %) and hexavalent chromium (up to 46.65 %).

The assessment of acute and chronic non-carcinogenic inhalation effects of the test substances on the health of the population of the study area revealed that the permissible hazard coefficient ($HQ = 1$) was exceeded for aluminum and its compounds (up to 4.00 HQcr), suspended solids (up to 1.81 HQac, up to 6.02 HQcr), manganese (up to 1.29 HQcr), phenol (up to 2.05 HQcr), formaldehyde (up to 7.61 HQcr).

Based on the results of instrumental studies of the quality of atmospheric air in Bratsk for compliance with hygienic standards and assessing the risk to public health, a preliminary list of 15 chemicals was formed: nitrogen dioxide, aluminum and its compounds, benz(a)pyrene, benzene, suspended solids, dihydrosulfide, xylene, manganese, methyl mercaptan, carbon disulfide, carbon

oxide, phenol, formaldehyde, gaseous fluoride compounds, ethylbenzene.

Based on the results of the conjugate assessment (Table 1) of preliminary lists of substances formed according to the assessment of the comparative hazard index, hygienic assessment of the results of instrumental studies and assessment of public health risk, a list of priority pollutants (27 compounds) recommended for monitoring on the territory of Bratsk was proposed: nitrogen dioxide, nitrogen oxide, aluminum and its compounds, benz(a)pyrene, benzene, suspended solids, suspended particles PM_{2.5}, suspended particles PM₁₀, hydrogen chloride, dihydrosulfide, dimethyl sulfide, xylene, manganese, methylmercaptan, sulfur dioxide, sulfuric acid, carbon disulfide, turpentine, toluene, carbon, carbon oxide, phenol, formaldehyde, poorly soluble inorganic fluorides, gaseous fluoride compounds, chlorine, ethylbenzene.

Table 1 Summary table of the connected assessment results for determining the list of priority substances for the tasks of monitoring the atmospheric air quality in the territory of the city of bratsk *

Item no.	Name of substance	High HRI value	Excess of MPC	Excess of acceptable risk levels
1	Nitrogen dioxide	+	+	-
2	Nitrogen oxide	+	-	-
3	Aluminum and its compounds	+	+	+
4	Benz(a)pyrene	+	+	-
5	Benzene	+	+	-
6	Suspended substances	+	+	+
7	Hydrogen chloride	+	-	-
8	Dihydrosulfide	+	+	-
9	Dimethyl sulphide	+	-	-
10	Xylene	-	+	-
11	Manganese	-	-	+
12	Methyl mercaptan	+	+	-
13	Sulfur dioxide	+	-	-
14	Sulphuric acid	+	-	-
15	Carbon disulfide	-	+	-
16	Turpentine	+	-	-
17	Toluene	+	-	-
18	Carbon	+	-	-
19	Carbon oxide	+	+	-
20	Phenol	+	+	+
21	Formaldehyde	-	+	+
22	Poorly soluble inorganic fluorides	+	-	-
23	Fluoride gaseous compounds	+	+	-
24	Chlorine	+	-	-
25	Ethylbenzene	+	+	-
26	Suspended particles PM _{2.5} **	-	-	-
27	Suspended particles PM ₁₀ **	-	-	-

* “+” means the presence of the indicator, “-“ means its absence.

** Included in the monitoring program in accordance with the WHO recommendations for ambient air quality [12–15].

The results obtained were taken into account when optimizing the air quality monitoring program in Bratsk for 2020. The assessment of the adequacy of the formed monitoring program, taking into account the list of priority substances, showed that according to the data of the Branch of the Federal Budgetary Institution of Healthcare "Center for Hygiene and Epidemiology in the Irkutsk Region" in the city of Bratsk and Bratsk District, in the period from January to May 2020, excess was recorded for 16 priority substances: nitrogen dioxide (up to 5.4 MPCmot), benz(a)pyrene (up to 4.7 MPCad), benzene (up to 3.3 MPCmot), suspended solids (up to 3.9 MPCmot), suspended particles PM2.5 (up to 2.6 MPCmot), xylene (up to 1.7 MPCmot), methyl mercaptan (up to 4.2 MPCmot), sulfur dioxide (up to 1.3 MPCmot), toluene (up to 1.8 MPCmot), carbon (up to 1.8 MPCmot), phenol (up to 10.0 MPCmot), formaldehyde (up to 1.9 MPCmot), gaseous fluoride compounds (up to 5.5 MPCmot), fluorides poorly soluble inorganic (up to 1.4 MPCmot), chlorine (up to 2.7 MPCmot), ethylbenzene (up to 2.9 MPCmot).

According to complaints from the population about a specific strong odor, during this period, measurements of mercaptans were carried out: 1-butenediol and propane-1-thiol, which also showed excess up to 6.5 MPCmot and up to 9.3 MPCmot, respectively.

Thus, the excess in 2020 was registered for 16 out of 27 substances included in the priority list: nitrogen dioxide, benz(a)pyrene, benzene, suspended solids, suspended particles PM2.5, xylene, methyl mercaptan, sulfur dioxide, toluene, carbon, phenol, formaldehyde, gaseous fluoride compounds, poorly soluble inorganic fluoride, chlorine, ethylbenzene.

The results of the spatial assessment of the location of the air quality monitoring posts and the zone of its representativeness (radius 5 km around the observation post) [16] (Fig. 1), taking into account the number of residents, showed that monitoring covered 208.755 thousand people or 92.3 % of the total population Bratsk.

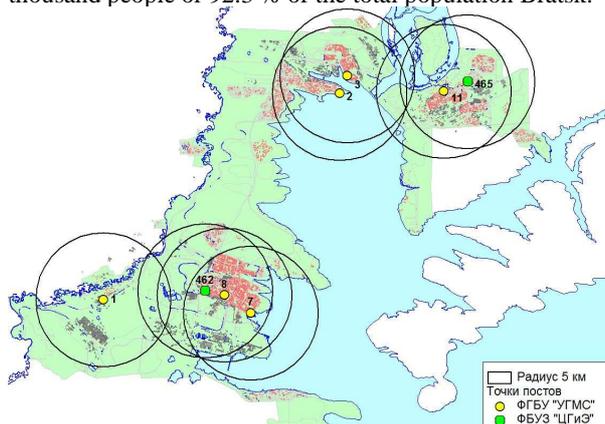


Figure 1 Location of air monitoring posts and areas of their representativeness.

4. CONCLUSION

The creation of a program for monitoring the quality of atmospheric air requires a scientifically grounded determination of the list of priority pollutants, taking into account the criteria of the formed health risk and exceeding the air quality standards based on retrospective data.

Based on the results of the comparative hazard index assessment, 21 priority substances were included in the preliminary list.

According to instrumental monitoring of the quality of atmospheric air, the excess of hygienic standards in the period 2014–2019. were registered for 14 substances (up to 34.8 MPCmot and up to 9.0 MPCad).

The total individual carcinogenic health risk exceeded the acceptable level for children and adults: TCR up to 1.52×10^{-4} and up to 1.63×10^{-4} , respectively. The assessment of acute and chronic non-carcinogenic inhalation effects of the test substances on the health of the population of the study area revealed that the permissible level of the hazard coefficient ($HQ = 1$) was exceeded for 5 analyzed substances (up to 1.81 HQac and up to 7.61 HQcr).

According to the data of the conjugate assessment of the research results, 27 substances are included in the list of pollutants for monitoring the quality of atmospheric air in the territory of Bratsk: nitrogen dioxide, nitrogen oxide, aluminum and its compounds, benz(a)pyrene, benzene, suspended solids, PM2.5 suspended particles, suspended particles PM10, hydrogen chloride, dihydrosulfide, dimethyl sulfide, xylene, manganese, methyl mercaptan, sulfur dioxide, sulfuric acid, carbon disulfide, turpentine, toluene, carbon, carbon oxide, phenol, formaldehyde, inorganic fluorides, poorly soluble, fluoride, gaseous chlorides.

The optimization of the monitoring program, taking into account the list of priority substances, showed that for the period from January to May 2020, according to monitoring studies, 16 out of 27 substances were registered in excess (up to 10.0 MPCmot and up to 4.7 MPCad).

Taking into account the spatial location of the existing air quality monitoring posts, monitoring covered 208.755 thousand people (92.3 % of the total population) in Bratsk.

The formation for the entire territory of Bratsk of consolidated databases on stationary and mobile sources of atmospheric pollution, followed by calculations of the dispersion of impurities, will allow updating and optimizing the list of priority pollutants in the study area and suggest points of the optimal location of posts for the task of monitoring the entire residential area of Bratsk. This task is the next stage in the research of the authors of this article.

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