Features of atmospheric air pollution in Ulan-Ude

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Abstract. At present, the study of atmospheric air in urbanized areas is a highly topical issue in the Russian Federation and many worldwide countries. The article studies the existing system for monitoring the state of atmospheric air in Ulan-Ude. The analysis of air pollution in Ulan-Ude for the period 2010–2019 has been implemented. The role of autonomous heating sources, thermal power plants, and vehicles as air pollution sources in the city has been determined. The dynamics of changes in the primary pollutants are given: sulfur dioxide, carbon monoxide, nitrogen oxides, and other impurities. As a result of the study, the primary sources of pollutants were identified that affect the state of the atmospheric air in Ulan-Ude, characterized by a seasonal increase in the concentration of pollutants emitted into the surface layer of the atmosphere. The influence of vehicles on air pollution in Ulan-Ude is revealed. The authors proposed a systematic approach to the control of atmospheric air pollution for Ulan-Ude.

1. Introduction

In 2018, the Federal Project “Clean Air” was launched to implement measures to reduce pollutants’ emissions into the air. The project provides a 22% reduction in harmful emissions into the atmosphere by 2024 compared to 2018. However, despite the Republic of Buryatia’s inclusion for several years in a row in the Priority list of regions with the highest level of air pollution in the Russian Federation, the city of Ulan-Ude has not included this list. As shown by the data on the priority constituent entities of the Russian Federation in terms of the specific gravity of atmospheric air samples from urban areas with an excess of MPCmr in 2019, the Republic of Buryatia, with an indicator of 3.35%, is again on the top line [1]. For comparison, the average specific gravity of these samples in Russia is 0.59%. At the end of 2020, Roshydromet, with the participation of Rospotrebnadzor, proposed to increase the number of settlements, i.e., participants of the above project to 48. The updated list also included Ulan-Ude and two settlements of the region, namely, the city of Gusino-Ozersk and the village of Selenginsk.

We also note that the system for monitoring the atmospheric air of settlements created back in the 20th century and still in operation, unfortunately, does not provide a full picture of the ecological situation in cities growing geographically and in terms of the number of inhabitants. An insufficient number of observation posts of the urban atmosphere monitoring system, physical and moral obsolescence of the instrument base, unreasonable location, discrete observations (3–4 times a day). These processes reduce the effectiveness of the implementation of control and supervisory measures on the part of state bodies to detect excessive levels of pollutants in the air. In this regard, there is growing interest in scientific research devoted to the problems of atmospheric air pollution from various sources both in Russia and abroad [2–6]. The current mechanism for monitoring the quality of
atmospheric air in cities, which is based solely on instrumental control methods, does not accurately result in the study of most pollutants entering the atmospheric air. This fact is because, for many pollutants, standardized measurement procedures have not been approved at the state level.

2. Materials and methods

Our analysis of the atmospheric air state in Ulan-Ude is based on open statistical data from statistical institutions of the Russian Federation and the Republic of Buryatia, data from the Buryat Center for Hydrometeorology and Environmental Monitoring – a branch of the FSBI "Zabaikalskoe UGMS," the Center for Hygiene and Epidemiology in the Republic of Buryatia, which ensures the activities of the Office of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare in the Republic of Buryatia, as well as its field studies. The methodological basis for the study was: the methods of systematic, statistical analysis and the Methodology for determining the emissions of harmful (polluting) substances into the atmospheric air from road traffic flows moving along the highways of St. Petersburg was applied (2018).

3. Results

The analysis of the existing air monitoring system in Ulan-Ude has been carried out. This analysis indicates that the current mechanism for monitoring the quality of atmospheric air in the city is based solely on instrumental control methods, which do not give an accurate result in studying most pollutants entering the atmospheric air. The reason is that for many pollutants, no standardized measurement methods have been approved at the state level.

The sampling of atmospheric air to detect the presence of pollutants in the city is carried out by the Buryat Center for Hydrometeorology and Environmental Monitoring, the Center for Hygiene and Epidemiology in the Republic of Buryatia, the Laboratory of Physical Problems of the BSC SB RAS. Samples show the presence and concentration of pollutants with the highest specific gravity in the total annual volume and typical for Ulan-Ude: benzopyrene, suspended solids, carbon monoxide, sulfur dioxide, nitrogen dioxide, as well as formaldehyde, phenol, and many heavy metals. Measurements of quality indicators of atmospheric air are made following the requirements of RD 52.04.186-89 "Guidelines for the control of atmospheric pollution" [7].

The analysis of the state of the Ulan-Ude air basin by the Buryat Center for Hydrometeorology and Environmental Monitoring is held at three automatic control stations (ASK-A) of atmospheric air pollution, which are located at the addresses: No. 1 – Zheleznodorozhny District, Prospect 50 Let Oktjabrya, 15; No. 2 – Oktyabrsky district, Babushkina street, section No. 16; No. 6 – Zheleznodorozhny District, Revolution Street 1905, plot No. 74. At the observation posts for each of the pollutants presented, an average of 900 samples are taken during the year.

The laboratory for air control of the Center for Hygiene and Epidemiology in the Republic of Buryatia is engaged in the study of concentrations of harmful substances for 38 indicators, such as benzopyrene, suspended solids, nitrogen oxides, sulfur dioxide, hydroxy benzene (phenol), carbon oxide, aromatic hydrocarbons (benzene, xylene, toluene ), formaldehyde and others. The following territories have been identified as receptor points for the center: Vostochnoy settlement; settlement Kirzavod; the center of the Soviet district; 19 quarter; 47 quarter. At these stations, one-time observations are made, on average, 50–60 samples per year for each air pollutant [8].

For preventing the toxic effect of atmospheric pollutants on health and the human body, the maximum permissible concentration is determined – MPC (MPCss – average daily and MPCmr – maximum one-time).

According to the analyzed data in 2019, 93.21 % of the total atmospheric air samples corresponded to the MPCd. This figure is 4.57 % higher than in 2017, in which the compliance of samples with standards was only 88.64 % of samples. However, this indicator does not detract from the total annual volume of pollutants (Figure 1).
It is necessary to consider that a prolonged stay within the boundaries of settlements with a high level of air pollution leads to such negative consequences for residents as constant low-dose exposure to toxicants. The likelihood of the following processes' occurrence and development significantly increases: toxic, mutagenic, carcinogenic, embryotoxic, and other harmful effects on the population's health in general and each inhabitant in particular. Simultaneously, the probability of various diseases of the population is the higher, the longer the exposure to pollutants in the air is carried out.

Figure 2 shows the average annual concentration of pollutants in the air of the city.

The data presented indicate exceeding the maximum permissible average annual concentrations in 2019. MPCs of benzopyrene (a substance of the first hazard class, possesses carcinogenic and mutagenic properties) exceeded by 11.95 times. According to the Buryat Hydrometeorological Center, in December 2020, benzopyrene exceeded the norm by 29.4 times. This circumstance is promoted by climatic (strong temperature inversions in winter combined with weak winds) and topographic conditions (mountain-depression relief), which are very unfavorable for dispersing pollutants and facilitating their accumulation in the lower atmosphere. Among other things, the main pollutants are operating in an enhanced mode – sources of heat supply: the enterprises of Generation of Buryatia, PJSC TGK-14 (CHP-1 with a 23% share in the total volume of emissions of pollutants into the
atmosphere in Ulan-Ude in the context of the main enterprises in the 2019 year, CHP-2 – 14 %), boiler houses of the Ulan-Ude energy complex of PJSC TGK-14 – 8 %) [7].

The excess of the maximum permissible average annual concentrations in 2019 was also noted for the following pollutants: suspended substances – 1.5 times, formaldehyde – 1.2 times, and hazardous fine suspended particles PM10 in 1.07, PM2.5 – 1.34 times. It should be noted that there is an increase in the level of average annual concentrations of sulfur dioxide, carbon (soot), ozone, formaldehyde, carbon oxide [9].

Regarding the structure of sources of atmospheric pollutants in Ulan-Ude, an increase in the share of emissions from transport and autonomous sources of heat supply – AIT (private sector furnaces, the predominant type of development in recent years) has been revealed. The study of the main sources of atmospheric pollution, commissioned by the Ulan-Ude Administration and started back in 2012 by specialists from the St. Petersburg Institute of Applied Ecology and Hygiene, showed a disappointing result. For the first time, a survey of private sector houses and the level of harmful emissions from cars was carried out (field studies of the composition and intensity of traffic flow on the Ulan-Ude roads were carried out). The study made it possible to distinguish that CHPP-1 contributes to the maximum surface concentration of sulfur dioxide. This pollutant co-occurs in emissions from industry, as well as vehicles and AIT.

Analysis of the data of the Consolidated Project of Maximum Permissible Emissions in Ulan-Ude in 2018 identified about 3.5 thousand industrial sources of air pollution in the city. Figure 3 presents the distribution of the share of the primary sources of atmospheric pollution.

Figure 3. Structure of sources of pollutants in the atmosphere of Ulan-Ude at the end of 2018

Figure 4 shows the total amount of air pollutant emissions in Ulan-Ude from numerous stationary enterprises and mobile sources in most road transport.

In the Republic of Buryatia, in 2018 (to 2016), there is a nine-fold increase in quantitative indicators for the main air pollutants near highways. And in the zone of influence of industrial enterprises, an increase of 4.2 times was noted (Figure 5).

The analysis of the data of "State reports on the state and protection of the Republic of Buryatia's environment" for the period from 2010 to 2019 was carried out. The analysis carried out indicates an increasing share of pollutant emissions into the city's atmospheric air by the exhaust of motor vehicles. On average, the increase in emissions for many analyzed years is 50.5 %. Among the main air pollutants are carbon monoxide (about 70 %), nitrogen oxides (77 %), as well as volatile organic compounds, which include a complex mixture of hundreds of carbon-containing gases (85 %).
We do not dispute the fact that highways located near settlements have a significant negative impact on the state of the atmospheric air in these territories. Simultaneously, there is a parallel picture of a constant increase in the number of road transport, which significantly aggravates the current situation [7, 8, 10].

We also note that in September 2020, the Baikalekodeystvie social and ecological foundation of the Republic of Buryatia, within the framework of the WWF-Russia project "People for Nature", with the participation of residents of Ulan-Ude, created a public monitoring network to monitor the state of the atmospheric air. For calculating the air quality index (AQI) according to the WHO recommendations, such indicators are measured as PM 10 and PM 2.5 – fine suspended particles (note that the settling rate of PM 2.5 is 15 times lower than for PM10) as well as carbon dioxide. As a result of monitoring, it was revealed that the air quality index deteriorated from "moderate" to "unhealthy" at the beginning of the heating season. Maximum PM2.5 values over 200 (hazardous to health) were recorded: in October 2020 – Ivolinsky lane (300 mg/m³), Priozernaya street (297 mg/m³), Garmaeva street (232 mg/m³); in November 2020 – Ivolinsky lane (300 mg/m³), Garmaeva street (286 mg/m³), Republican lane (214 mg/m³), Priozernaya street (297 mg/m³), Pervaya street (209 mg/m³), Trubacheeva street (229 mg/m³).
4. Discussion
The analysis of the monitoring data of atmospheric air pollution in the city indicates the presence of such a significant factor as seasonality in the distribution of average monthly concentrations of pollutants in the air of Ulan-Ude. So with the onset of the heating season, the concentration of harmful substances in the city increases to 20–40%.

The concentration of benzopyrene (a substance with a maximum excess of MPCss during the year) rises sharply from September to April. The maximum concentration of benzopyrene with multiple MPCss occurs in January, at the peak of cold weather. Most of the samples that do not meet hygienic standards (9.2%) for 11 months of 2020 reveal an excess of benzopyrene up to 33 average daily maximum allowable concentrations. The primary sources of benzopyrene entering the atmospheric air are combined heat and power plants, private boiler houses, and motor vehicles.

A sharp increase in sulfur dioxide concentration is observed in January and February because winter in the region is the most unfavorable period for dispersion of atmospheric impurities; calm and stable inversions are observed.

Fluctuations in the maximum permissible concentration of carbon monoxide are also seasonal. A higher level is also observed during the heating season. A significant weight in the volume of carbon monoxide pollution is made up of emissions from vehicles, a slightly smaller share is occupied by autonomous heating sources, the combined heat, and power plant.

5. Conclusion
Our analysis of the state of atmospheric air in Ulan-Ude indicates a serious environmental problem in the city associated with a high level of air pollution. According to numerous studies in 2019-2020, Ulan-Ude is one of Russia's ten most disadvantaged cities in terms of atmospheric air pollution.

The analysis of atmospheric pollution in Ulan-Ude should be carried out based on a multivariate model. Firstly, the prevailing climatic and topographic conditions lead to such negative phenomena, in diseases of the constantly growing amount of pollutants in the air, as a decrease in air masses' circulation. Almost all chemical impurities getting from pollution sources into the city's atmosphere do not dissipate; there is frequent stagnation of air, especially in winter, which leads to the accumulation of pollutants in the surface layer of atmospheric air in Ulan-Ude.

In our opinion, the optimal way to improve the quality of the air monitoring system in cities is the integrated application of both instrumental and calculation methods for assessing and controlling emissions from various sources of pollutants, for example, using the methodology for determining emissions of harmful (pollutants) substances into the atmospheric air from motor vehicles. Flows moving on the highways of St. Petersburg (2018), including considering such qualitative parameters of road traffic flows as speed, intensity, structure, flow density, and the value of specific run-off emissions and specific emissions in areas of road crossings.

Acknowledgments
The study was carried out as part of a 2020 grant for innovative scientific research at Dorzhi Banzarov Buryat State University.

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