Using of summary calculations for assessment of air pollution in the urban habitat in the Arctic region

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Abstract. This article discusses the possibility of using summary calculations as a standard for assessing the quality of the city air. Murmansk, like many industrialized Arctic cities, has its own specifics of development, which leads to an increase in the concentration of pollutants in the urban atmosphere, which negatively affects the health of the population and the urban environment quality. There is an air quality management system in Russia, but for many reasons it is imperfect. At the same time, along with it, there is a practice of applying summary calculations to assess air pollution by emissions from road transport and industrial facilities, which allows getting a more detailed picture of the atmospheric air quality. The authors of this article compared the results of assessing of pollutants distribution in the atmosphere of Murmansk city, obtained by using of summary calculations and actual indicators of hazardous components content in the air. The objectivity of summary calculations maps and the possibility of their use for predicting the distribution of air pollution in Murmansk are determined.

1. Introduction
The priorities of Russia's new policy in the Arctic [1] are the economic development of the northern territories, the transformation of the Arctic zone into an industrial and infrastructural region. Achievement of the region development goals can lead to a sharp increase in the man-caused pressure on environmental components, including the atmosphere of industrial centers and cities in the Arctic, which, as a rule, also formed around the industrial core of the Arctic territories [2, 3]. At the same time, the new "Strategy for the Development of the Arctic Zone" [1] provides for the development of environmental monitoring tools and minimization of harmful substances emissions when organizing activities in the northern territories.

The largest Russian enterprises of the mining and construction industry, nonferrous metallurgy, the military complex, and energy enterprises are located in the Murmansk region. Their activity often responsible for serious changes in natural ecosystems, a high negative load on the environment, and a critical level of air pollution [4, 5].

In addition to the existing anthropogenic load, the region is characterized by special natural and climatic conditions: low air temperatures, winds, snow cover for a longer time of the year, etc., which can deteriorate the conditions for dispersion and assimilation of air pollution.
The development and functioning of the urban environment in the Arctic region also has its own special aspects, and at the same time, in general, this development is influenced by several negative impact factors: an increase in the number of industrial sites, a constant increase in the intensity of transport, expansion and compaction of buildings. These factors lead to an increase in the concentration of pollutants in the city’s atmosphere and an increase in the negative anthropogenic load on the environment and public health [6, 7].

An important condition for maintenance of the natural air quality is timely comprehensive work on the assessment and regulation of emissions from all sources of pollution. To do this, it is necessary, firstly, to receive relevant and reliable information about the results of the inventory of emissions from these sources, and secondly, to have a strict legislative base that regulates the handling of such types of work.

2. Legislation of the Russian Federation in the field of regulation of pollutants emissions

At present, in Russian Federation the air quality management is assigned to users of natural resources (organizations and enterprises). Every user is obliged, according to the legislation, to carry out an inventory of hazardous emissions into the atmosphere, the results of this inventory are then used depending on the category of the enterprise and its impact on the environment degree. For example, to establish standards for maximum permissible emissions or for transmission to supervisory authorities in a form of declaration or notification [8, 9]. These types of environmental documentation are then used as a benchmark (initial information) for estimation of the hazardous impact of enterprises and other organizations on the atmospheric air.

At the same time, situation concerning records of emissions into the atmosphere from vehicles remained ambiguous for a long time. From May 10, 2017, only emissions from closed parking lots, boxes and other similar facilities equipped with a ventilation system were subject of regulation. The pollutants released into the atmosphere from cars and open parking lots were not standardized and were not taken into account in the environmental documentation of enterprises. Private vehicles were not mentioned at all [10].

The "Procedure of the inventory of harmful substances into the atmospheric air from stationary sources and emissions ..." was approved in 2018 [11], but it also did not contain any information concerning the inventory of vehicle emissions for assessing air pollution.

According the amendments introduced from January 1, 2019 to the Federal Law "On the Protection of Atmospheric Air" [12] an inventory of hazardous emissions into the atmosphere (both from stationary and mobile sources) is plainly required for legal entities and individual entrepreneurs. However, it was still impossible to take an inventory of mobile sources, because new amendments did not contain any information about the procedure of an inventory of hazardous emissions from vehicles [16].

Nevertheless, the analysis data of the Murmansk city air pollution showed that, although all enterprises had approved volumes of emissions according to the established standards (in other words they operated within the framework of permitted emissions), the total level of city atmosphere pollution at a number of points had significant excess in terms of background pollution [13]. This indirectly testified to unaccounted sources of urban air pollution.

In the beginning of 2020, the "Methodology for determining emissions of pollutants into the atmospheric air from mobile sources for carrying out summary calculations of air pollution" [14] came into force. According this methodology the calculation of the pollutant emissions values from vehicles has been made possible and it takes into account their contribution to air pollution in settlements.

3. The system of summary calculations of atmospheric air pollution by emissions from industrial enterprises and vehicles

At present, the solution of problems with ensuring air purity can be effective only in the case of an integrated approach, when the total contribution of emissions from both industrial enterprises and vehicles are taken into account in assessing city’s air pollution [12]. At the same time, there is a need
to implement a universal system for monitoring and managing the quality of atmospheric air on the scale of cities, their districts, or entire regions.

The solution of this problem can be the introduction of a system of summary calculations of air pollution by harmful substances that enter the atmosphere from industrial enterprises and vehicles in a certain area, because such a system allows to take into account information about emissions from all atmospheric air pollution sources (APS) of a city (district) in aggregate.

Summary calculations are performed using the appropriate approved methodology [15]. To account for emissions from industrial enterprises, the initial data when conducting summary calculations are the values obtained during the inventory of stationary sources of atmospheric pollution. To account for emissions from urban vehicles, as the initial data can be used the results of calculating emissions according to the previously mentioned method [14], obtained by processing the results of field surveys of the parameters of road transport flows, using the recommended specific emission factors, differentiated by the main large groups of vehicles. For the entire set of urban sources of atmospheric air pollution, a calculation of emissions dispersion is carried out, taking into account the parameters of the sources themselves, the terrain, the climatic characteristics of the region, etc.

The calculation of pollutants dispersion in the atmospheric air according to the methodology approved in 2017 [15], as well as the previous OND-86 [17], is based on a mathematical regression model and approximation of the difference solution of the turbulent diffusion equation. Due to this, it is possible to take into account the influence of built-up area (location of buildings) on the dispersion of substances in the atmosphere in the calculation, as well as traffic flows. The set of values of the surface concentration of a substance when it is disperse in the atmosphere can be calculated at any point in the area in the presence of several sources. At the same time, the number of pollution sources can reach fifteen thousand, and the list of pollutants under consideration contains more than 200 items. The calculation is performed by summing the concentrations calculated for each individual source, taking into account the specified values of the wind speed and direction. In this case, the calculation of pollutants concentrations released into the atmosphere from a certain group of sources can be reduced to the calculation of emissions from a single source.

Thus, the concentrations of hazardous compounds formed by emissions from a set of sources are reduced to the calculation of emissions from each single source.

According to methodology for determining of emissions diffusion in the atmosphere [15], when gaseous substances and aerosols are emitted from a point source, the highest concentration of pollutants in the zone of human breathing can be achieved at a certain point and its location depends on the terrain features, including the topography and climatic conditions, and parameters of the APS itself. Climatic parameters include a coefficient that takes into account the atmosphere high-rise stratification; minimum and maximum average temperatures of the cold and warm seasons and the prevailing wind regime. APS parameters take into account its size, position in space, chemical and physical properties of emitted substances, concentration and rate of release of aerosols and gases from the mouth.

Existing highways with traffic flows should be considered as linear sources during realization of calculations.

Finally, the concentration of any substance from the complex of all sources of production and (or) transport in a point of detail is made up by the sum of the concentrations of this substance from the set of all sources of the city. The results of these calculations form the summary calculations.

Concentrations of pollutants obtained as a result of summary calculations at multiple points of the city are presented graphically. Contours with concentrations of pollutants are plotted on the urban topographic base.

Summary calculations are a universal system for calculating atmospheric pollution that will allow solving a number of environmental monitoring problems both in small settlements and in large cities with a population of more than half a million people. Computational monitoring is based on the regular determination of the spatial and temporal characteristics of air pollution using mathematical models of diffusion of atmospheric impurities and their transfer, at the same time the initial data for it...
are inventory data of various parameters of emission sources with the indispensable consideration of meteorological and climatic characteristics. The need for such monitoring is explained by the fact that during instrumental monitoring of atmospheric air quality, which is carried out by regional divisions of the Russian Hydrometeorological Service, based on information from stationary observation posts, the amount of received data is not enough to form a correct picture of atmospheric air pollution in the urban environment [13]. The summary calculations are of particular importance in relation to accounting for specific pollutants, for which at present time there are no methods of instrumental control, or observations cannot be carried out on an ongoing basis [19].

For example, in the city of Murmansk more than a thousand stationary pollutant sources and more than one hundred thousand vehicles are currently registered. At the same time in the city at the moment there are only 3 operating stationary pollution monitoring posts, and the amount of controlled pollutants is less than 20, although much more is emitted. Thus, it is impossible to obtain real values of background concentrations of all emitted substances on the territory of an entire city or region using only instrumental monitoring. In this case, a system of summary calculations can become a significant addition to instrumental monitoring, since it allows obtaining reliable information on the general pollution of urban air.

As an example of successful modeling of atmospheric air pollution in a city using summary calculations, can be the assessment of the distribution of pollution in the atmosphere of Murmansk, carried out by the authors of this publication. The estimation was carried out in relation to a number of harmful substances (suspended solids, sulfur dioxide, nitrogen dioxide, carbon monoxide, saturated C1-C5 hydrocarbons, C6-C10 hydrocarbons) and made it possible to obtain a detailed picture of the territorial distribution of their maximum concentrations. An example of the modeling results of distribution of inorganic dust with a SiO2 content of 70-20% in the atmospheric air of a city is shown in Figure 1 as a pollutant dispersion map. The results were verified by taking and analysis of air samples at ten points with the highest priority in the city.

It was found out that the content of most of the investigated compounds in the air of Murmansk did not exceed the maximum permissible concentrations (MPS). At the same time, it was revealed that the quality of atmospheric air does not correspond to the normative in terms of the suspended solids concentrations, which in 50% of the samples taken exceeded the established MPC.

At an MPC of suspended solids of 0.5 mg/m3, its concentration in the city’s air exceeded permissible maximum in the range from 0.65 to 0.83 mg/m3, or from 1.30 to 1.66 proportion of MPC respectively. The highest concentrations of 1.66 proportion of MPC were found in the Leninsky district of the city, in the industrial site, at the intersection of Sverdlova and Domostroitelnaya streets, also in the Oktyabrsky district, at the intersection of major highways of Lenin Avenue and Akademik Knipovich Street. Exceeding the permissible concentrations was recorded in all areas of the city, both at industrial sources and near highways (Figure 2).

The current situation of air pollution with suspended solids, contrary to the forecasts of consolidated calculations, is explained by the sampling period. Air quality analysis for this pollutant was carried out in the spring period after the melting of the snow cover and before full-scale vegetation; also, due to the temperature rise in Murmansk, the relative air humidity decreases [18]. All of these factors contribute to a decrease of fine particles adhesion, and due to this an increase in dust formation and secondary uplift of settled particles.

Thus, a comparison of the obtained actual data with the maps of summary calculations of atmosphere pollution in Murmansk showed the objectivity of the maps of summary calculations and confirmed the possibility of their use to predict the distribution of air pollution in Murmansk. The obtained modeling data, which characterize the formation of fields of pollutants concentrations in the atmosphere of Murmansk, can also be taken into account when justifying and assessing planned solutions for the development of the urban environment, for the formation of public spaces and recreation areas, the creation of industrial and residential areas, as well as for the reconstruction of the transport and road networks, substantiating decisions on the possibility of reconstruction and re-profiling of existing production facilities [19, 20].
Figure 1. The results of modeling dust pollution of the inorganic (SiO2 70-20%) atmosphere in Murmansk
4. Conclusion
The solution of urban development problems cannot be ensured without the development of a monitoring system and without control of the quality of air in the urban territory of modern cities. The implementation of the development strategy for the Arctic region should be based on reliable and comprehensive forecast and monitoring of environmental effects, for example, on the system of summary calculations for modeling and forecasting of air pollution. In many respects, there is no alternative to summary calculations, especially when it comes to complex monitoring of the territory, forecasting the impact of the implementation of various environmental protection measures, predicting the impact of various measures taken for the development of the urban environment, both in general and in terms of its individual territories and systems on the quality of atmospheric air, identifying environmental problems of atmospheric air in settlements.

The development of a summary calculation system for the city of Murmansk can be considered as an initial stage in the creation of new "green" standards in the Arctic zone of the Russian Federation, aimed at focusing on environmental protection and air pollution reduction.

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