Methodology for comprehensive assessment of atmospheric air state in populated areas

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Abstract. The article describes the development of a methodology for a comprehensive assessment of the main sources of pollution and factors affecting the state of atmospheric air in populated areas. Its main distinguishing feature is that it takes under consideration the type of development of the selected area when assessing the impact of vehicles. Another important feature is the consideration of the estimated impact of new construction facilities, demolition of buildings and structures on populated areas, as well as the impact of unfavorable (dusty) areas as air pollution sources. The application of the proposed methodology makes it possible to conduct a comprehensive assessment of the main pollution sources and factors affecting the state of atmospheric air in the populated areas and categorize the city territory for making decisions on the possibility of locating new construction facilities in the urban area.

1. Introduction
A modern city is a complex system with all elements interconnected. The changes made to one of them entail changes in all the components of a system as a whole.

The urban environment, as a life support system, should satisfy the social, economic, aesthetic and ecological needs of a person in the best way providing an environmentally sound quality of life [1-3].

In large cities, the overconcentration of population, vehicles and industrial enterprises in relatively small areas, with the formation of environmentally unbalanced anthropogenic landscapes, causes environmental problems.

The emissions of harmful substances from stationary and mobile sources of pollution, with prolonged exposure, can cause serious diseases of the lungs and upper respiratory tract or even lead to death. These problems are particularly relevant in large cities, where the concentration of some harmful substances often exceeds their maximum permissible concentration (MPC), in view of the rapid industrial development in these cities. As a result, stationary sources of pollution (factories, plants, etc.) are located so densely that contaminated areas often overlap thus forming unfavorable and even life-threatening zones. Mobile sources, such as road transport, also contribute to the level of pollution, the traffic density of which is also constantly increasing every year.

Another factor affecting human health in a large city are uncomfortable dusty areas [4-7].

The aforementioned phenomena provide grounds for stating that research in this area is extremely important not only for protecting the environment, but also for protecting public health.
2. Development of a methodology for a comprehensive assessment of the main sources of pollution and factors affecting the state of atmospheric air in populated areas

To make environmentally sound decisions at all stages of the life cycle of construction facilities, from their design and operation to demolition, it is necessary to form a system of environmental monitoring of atmospheric air, taking into account the urban development of populated areas.

The first step towards making up such a system is to develop a methodology for a comprehensive assessment of the main pollution sources and the factors affecting the state of atmospheric air in populated areas.

There is a number of techniques making it possible to take into account individual aspects, both of the impact of stationary [8, 9] and mobile sources [10-13]. At the same time, there is no complex methodology or a software system supporting its implementation and allowing one to simultaneously take into account:

- assessment of the impact of vehicles, taking into account the type of development;
- assessment of the impact of stationary sources selected on the map;
- assessment of the impact of unfavorable areas;
- assessment of the impact of new construction facilities and demolition of buildings and structures as air pollution sources;
- assessment of the wind regime in the formation of the atmospheric air monitoring system.

The existing methods for assessing the impact of vehicles, with all their flexibility, do not fully take into account the factor of dispersion of pollutants among buildings, which is important for an integrated methodology.

As a starting point for assessing the impact of vehicles, taking into account the development type, GOST R 52398-2005 [14] was taken, which lists three categories of motor roads (speedways, highways and secondary roads). Automatic recognition of these road categories can be implemented by retraining the convolutional neural network, which the authors have developed for recognizing the development type [15].

Knowing the road type, one can determine the main parameters most affecting the level of air pollution with vehicle exhaust gases: speed, traffic intensity and its composition, i.e., what kind of cars are involved in road traffic.

In particular, the distribution of the intensity of traffic flows on the highways of the area under study can be visually represented on the map of the studied city territory in the geographic information system (Figure 1). To obtain the concentration of carbon monoxide in the middle of the carriageway, as well as at various distances from this carriageway, the calculation methods from GOST R 56162-2019 are used [16].

![Figure 1. Display of the traffic intensity of motor vehicles on highways on the map of the area under study.](image)
The results of such modeling turned out to be close to the data obtained during field measurements. When modeling the dispersion of vehicle emissions in the various development conditions, the methodology given in [17] was used. To take into account the development type, the authors have implemented a module for recognizing a building type [15]. The combination of these approaches makes it possible to assess the impact of vehicles for the studied city territory, taking into account the development type.

To assess the impact of the second factor (stationary sources), the calculations of pollution dispersion can be performed in accordance with the methodology approved by the order of the Ministry of Natural Resources of Russia No. 273 dated 6/6/2017 [18]. To assess the impact of the third factor (unfavorable territories), the indicators from paper [19] are used.

For each of these indicators, an assessment from 1 to 4 points is made, where the best indicators correspond to one and the most unfavorable ones to four. Thus, according to the improvement degree, the territory can be divided into 4 categories: favorable type of territory, favorable with some limitations, unfavorable and extremely unfavorable.

The location of unfavorable territories of the studied area of the city can also be visually represented in the geographic information system (Figure 2).

![Figure 2. Map of unfavorable territories of the studied city territory.](image)
Similarly, the impact of new construction facilities and demolition of buildings and structures as air pollution sources is assessed.

The assessment of the wind regime, as well as average temperatures for each month, are taken into account, when determining the dispersion of pollutants from stationary and mobile sources. In this case, unfavorable wind speeds for different sources are revealed, creating conditions for maximum air pollution or the spread of pollutants.

As a rule, this data can be obtained on the basis of long-term observations from the system of hydrometeorological centers of the analyzed territories.

3. Conclusion
The application of the proposed methodology makes it possible to carry out a comprehensive assessment of the main pollution sources and factors affecting the state of atmospheric air in populated areas, as well as to categorize the city's territories, according to the criteria the authors proposed in [20].

An example of categorizing territories is shown in Figure 3.

![Figure 3](image.png)

**Figure 3.** Categorization of the studied area according to the degree of environmental well-being.
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