Development of the analytical potential of territoriel air monitoring measuring systems

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Abstract. Air monitoring makes it possible to zone the urban environment according to the degree of technogenic impact, using significant socio-ecological and economic indicators to optimize management decisions for a wide range of applied tasks of territorial strategic planning. Fuzzy expert assessment uses the representation of knowledge in the form of linguistic variables, so it is important to provide the developer of software tools with reliable characteristics of the subject area of monitoring. Based on the critical analysis of the known approaches to the ranking of the territory according to the criteria of environmental safety, a matrix method for zoning the territory of an industrial agglomeration is developed and discussed for the coordination of two indicators – «specific ecological and economic damage» and «the coefficient of localization of aerotechnogenic load from stationary sources of emissions». The indicators best reflect the complex pollution of the territory and the complex causal operational and natural links in the chain: «technology → gas purification system→ source of emissions → dispersion of substances in the surface layer of the atmosphere → formation of an active pollution zone → damage». Ignoring the role of the spatial factor reduces the diagnostic potential of existing predictive automated emission control systems. The author's propositions are illustrated by the data on the air intensity of economic activity and the discussion of the prerequisites for the harmonization of Russian and international monitoring standards based on the principles of Directive 2004/35/CE11 of the European Parliament.

1. Introduction

1.1. Relevance of the issue
Ensuring the high quality of the urban environment is a strategic benchmark for sustainable development, the achievement of which is evaluated by the multidimensional and multifaceted "City Prosperity Index", recommended by the UN. Air monitoring makes it possible to objectively characterize the level of pollution, identify the problem areas of the territory that are most susceptible to environmental degradation, correlate their distribution with medical and environmental assessments of the population's health, and form an optimal urban environment management system. The territories of transport and industrial hubs, industrial zones, industrial agglomerations, and large livestock complexes are primarily subject to the threat of destruction and the need to take operational measures to change the nature of nature management.
The urgency of improving the system of regional environmental supervision in the direction of maximum consideration of sanitary and hygienic requirements increases against the background of COVID-19 and is expressed in the active search for new digital algorithms for managing the environmental safety of cities. The best practice of territorial strategic planning is based on the zoning of space according to the level of anthropogenic load by integrating the characteristics of many factors into a single irreplaceable formalized model and thereby expanding the "information framework in the development of a regional model of territorial planning" [1].

Information about atmospheric pollution is incomplete and unclear, so when describing the subject area in monitoring practice, it is necessary to develop the conceptual tools of fuzzy logic by introducing new linguistic variables that have a numerical interpretation [2]. The aim of the study is to develop a matrix method of ecological zoning of territories exposed to constant aerotechnogenic impacts in order to supplement the software of local monitoring systems.

1.2. The demand for developing the potential of monitoring systems
In the European Union, China and other countries, certified predictive emission control systems are widely used, combining hardware and software and implementing a specific mathematical model for processing the obtained measurement data. In the rigidly defined conditions of the technological regime (temperature, pressure, composition and flow rate, ratio of impurities), digital methods of statistical mathematical modeling complement the instrumental analysis of emissions in monitoring systems [3-5] and allow:

- to predict the concentrations of pollutants with high accuracy and simulate the processes of their dispersion in the surface layer of the atmosphere;
- to identify relationships, cause-and-effect relationships, and correlations between key operational process parameters and emission properties;
- to create stable trainable neural networks for solving problems of modeling, classification, forecasting, planning and optimization of emission flows in real time with an acceptable error.

The modern instrumental and technical base of monitoring and information technologies make it possible to achieve a qualitatively higher level of development of analytical substantiation of solutions to environmental safety issues through the integration of production systems into a single regional management center:

- identification of microdistricts of the city that are exposed to the highest level of man-made impact and risks for the most sensitive part of the population (children and adolescents);
- planning of optimization measures for the development of urban areas;
- implementation of programs for the improvement and landscaping of the territory;
- increasing the effectiveness of state control in land use;
- optimization of traffic patterns and traffic flows;
- planning the location of production facilities under construction;
- objective resolution of economic disputes between users of nature resources.

Domestic and foreign scientists have developed a wide range of original indicators and methods for assessing the state of the territory, indicating the priority of atmospheric pollution. For example, based on the assessment of the level of environmental risk of heavy metal pollution, the territory of the city of Kazan was clustered out [6]:

- cluster 0 «low degree of danger». Large open areas combined with high-rise buildings and high traffic density. Average or below average concentrations of pollutants in the surface layer of the atmosphere and heavy metals in the snow cover. The priority is given to the development of control actions for mobile sources of pollution;
- cluster 1 «medium degree of danger». Low-density buildings with wide streets near large enterprises, which are located outside the urban environment. Concentrations of toxicants vary from elevated for some impurities to average and below average for others, but always higher than in cluster 0. Priority is given to managing emissions from stationary sources;
• cluster 2 «high degree of danger». Dense low-rise buildings, the streets are loaded with motor traffic at a low speed. There are uneven concentrations of toxicants, isolated peak cases of contamination of the territory, for example, lead, cadmium and copper. Priority is given to the development of control actions for mobile and stationary sources.

Other researchers, when calculating the dynamic index of the quality of the urban environment in the «environmental safety» block, use the following indicators: a) the amount of pollutants per capita coming from all stationary sources (kg/person); b) the density of pollutants released into the atmosphere from all stationary sources (t/km²); c) the density of emissions into the atmosphere from road transport (t/km²) [7].

2. Discussion of the results of the study

2.1. Justification for the selection of criteria

American sociologists have shown that the behavior and anxiety of people living in polluted areas changes due to the violation of social, economic, physical and psychological patterns of life [8]. In the regions of Russia, the share of cities with constant monitoring of atmospheric air does not exceed 18%, and the share of observation posts-from 2 to 22% (table 1). Residents of Angarsk, Bratsk, Krasnoyarsk, Omsk, Chita are in the «smoke-filled» environment. Investments in air protection measures do not even reach 0.5 % of the GRP in those regions of the country where the highest indicators of «air capacity» are observed, calculated by us as the amount of emissions per one billion rubles of the cost of the created product.

Table 1. Indicators of air intensity of economic activity.

| Region (federal district) | Emissions per GRP, kg/billion rubles. | Investments in the calculation of the emissions, rub/t | The number of cities with an air pollution index of more than 7 | The share of fixed monitoring stations, % |
|---------------------------|--------------------------------------|------------------------------------------------------|-------------------------------------------------|--------------------------------------|
|                           | Gross emission                        | From stationary sources                               | Gross emission                                   | From stationary sources |
| Central region            | 222.4                                | 64.0                                                  | 329.5                                           | 1144,1                  | 3 | 18.0 |
| North-West region         | 428.0                                | 245.4                                                 | 3715.0                                          | 6477,1                  | 1 | 13.0 |
| South region              | 525.5                                | 185.6                                                 | 150.1                                           | 425.0                   | 2 | 8.5  |
| North-Caucasian region    | 561.4                                | 82.3                                                  | 148.8                                           | 1015.3                  | 1 | 2.1  |
| Volga region              | 519.5                                | 236.5                                                 | 811.0                                           | 1781.5                  | 0 | 22.0 |
| Ural region               | 553.0                                | 410.7                                                 | 4173.2                                          | 5619.1                  | 5 | 8.2  |
| Siberian region           | 1062.9                               | 808.4                                                 | 2093.2                                          | 2752.3                  | 27 | 19.7 |
| Fa East region            | 434.6                                | 239.5                                                 | 3754.0                                          | 6811.5                  | 5 | 8.6  |

\[a\] Compiled by the authors on the basis of State report «On the state and environmental protection of the Russian Federation in 2019».

The transition to the digital economy will inevitably lead to the expansion of methods and regulations for effective express analysis of the geocological situation and the typification of a specific area exposed to anthropogenic impact for environmental purposes, taking into account the identified urban features. The addition of observational data with computational and analytical methods allows us to obtain the necessary quantitative estimates of the consequences of negative impacts, to ensure the completeness and quality of information for making decisions on the budgeting of rehabilitation measures and projects.

In the context of the implementation of the state policy of technical regulation based on the principle of best available technologies (BAT) and due to the high resource costs, the choice of the prevailing pollutants in emissions (markers) that are subject to mandatory control by automatic systems is of fundamental importance. It is not always possible to reliably link markers with specific sources of their
formation, enterprises, and technological process, especially when the zones of contamination from a group of stationary sources in industrial sites overlap. A more effective methodological method involves the use of aggregated indicators for assessing the ecological state of the territory. The need to take into account the differences in the effects of toxicants on human health and the state of ecosystems when normalizing negative impacts is argued by the authors of the article [9]. They propose to calculate the «indicator of the total volume of emissions of pollutants into the atmospheric air», indicating at the same time the generalized and approximate nature of the information received. In our opinion, the uncertainty is explained by the fact that the list of enterprises required to monitor atmospheric air is determined by the territorial bodies of Rosprirodnadzor and Roshydromet, and not all enterprises of the city fall into this list. There are also unresolved issues un the organization of emission control, for example, the choice of the location of control points at the border of the enterprise, the determination of marker substances in the absence of industry-specific information and technical reference book BAT, the correct calculation of the border of an industrial site.

When choosing the criteria for zoning the territory according to the level of environmental tension, only significant factors are guided, ignoring insignificant indicators. However, the division of factors into two groups (major and minor) is a very complex and debatable issue. There is no consensus on how to take into account the potential for self-purification of naturel environments and the ecological capacity of the territory, how to determine the contribution of a particular enterprise to the total pollution.

To solve a wider range of administrative applied tasks, it is advisable to use the available and legitimate statistical reporting data, and to designate alternative territories (zones, sections, microdistricts) additionally involve key linguistic coordinates. The latter should not only reflect as much as possible the negative consequences of aerotechnogenic impact in the natural dimension (maximum permissible concentration, maximum permissible discharge, maximum permissible level, temporarily agreed discharge), but also have a universal cost estimate that is more understandable to a wide range of management specialists.

2.2. The territory positioning matrix
We have developed and proposed for discussion a management map-a matrix for positioning of sections of an urbanized territory according to the level of aerotechnogenic load, which can be built on the results of monitoring (figure 1). The plans and schedules of industrial environmental control of enterprises contain detailed information sufficient to implement the proposed method of positioning territories located in the zone of negative impact:

- names of the structural divisions where the sources are located;
- names and characteristics of sources of emissions of pollutants;
- frequency of control, location and methods of sampling;
- measurement methods and techniques used;
- calculated and instrumental methods of control on the sources of emissions.

We describe the proposed criteria:

1. Specific environmental and economic damage (Ds). It is calculated according to well-known methods and correlates with any publicly significant aggregated socio-economic result of activity, for example, the gross regional product, the gross emission of pollutants, the population, the area of the territory, etc. The category «damage» best reflects the role of the spatial factor in a complex chain of causal operational and natural relationships: «technology → gas purification system → source of emissions → dispersion of substances in the surface layer of the atmosphere → formation of an active pollution zone → damage». It is fundamentally significant that the concept of damage, in contrast to the total emission, takes into account the chemical and physical pollution of the territory, and, if necessary, biological pollution. This assessment category also coordinates with the international concept of «ecological footprint» used in ecosystem calculations and forecasts of the consequences of civilizational development.

J. Corlett, considering the damage as a result of conscious management decisions at the highest state level, notes that the growth of civil activity of the population does not allow democratic environmental
procedures to turn into a pure formality, encourages corporations to implement joint social projects and generates «a chain reaction of joint responsibility for potential dangers and for the creation of institutions that could prevent them» [10]. Collective systems of environmental monitoring of industrial enterprises should become such an institution.

2. The coefficient of localization of aerotechnogenic load from stationary sources of emissions (Klok). It is calculated as the ratio of the area of the local zone of active pollution created by a group of stationary sources of emissions to the total area of the urban industrial complex (industrial zone) where they are located. In industrial agglomerations, it is more likely that the total area of negative impact may be close to or greater than the area of the agglomeration itself. Consequently, the risks to the population and the ecosystems of the adjacent territories increase manifold. In large industrial cities, the increased density of hot, powerful sources of emissions and heavy traffic flows lead to the appearance of a stable "smoke frame" (active pollution zone) within a radius of 20-50 km.

![Figure 1. The positioning of the regions in terms of air pollution.](image-url)

When the Klok<1, the maximum concentrations of markers do not exceed the established standards and the background concentration, and most importantly – do not go beyond the industrial site and are localized in the area of area of responsibility of enterprises (the minimum level). With the value Klok=1, an acceptable (average) load level is observed, which means that there are no reserves of environmental protection capacities and a high probability of a critical risk for the pollution. At the value of Klok>1,
an acceptable (maximum) level of load is observed, and toxicant flows enter the adjacent residential area, increasing environmental tension and damage.

The zoning technique we have chosen represents eight types of territories, but this does not contradict, but, on the contrary, agrees well with the previously indicated cluster approach. Thus, all three types of territories can fall into the zero cluster with the lowest degree of risk when the value of the Klok indicator is <1 and the value of specific damage from the minimum to the maximum level, because the traffic flow plays the dominant role in the negative impact on the environment.

2.3. The applied aspect of the positioning matrix
According to the State Report [11], there are 1.5 million potentially dangerous objects in Russia that have a negative combined physical impact on human health (heat, noise, vibration, electromagnetic, laser and other effects). The proportion of facilities where it exceeds sanitary standards is steadily decreasing, although it remains high (about 10%). Therefore, in cities, areas of the territory of priority non-normalized physical pollution can be formed, which must necessarily be included in the environmental monitoring system.

The zoning of the territory is important for the budgeting of rehabilitation measures. The reduction of gas pollution in cities can be supported by the optimal aeration regime of the street space provided by urban planning tools and planning solutions. Thus, in dense buildings, it is necessary to study the conditions for the occurrence of a closed circulation of air masses that covers the street space and leads to increased gas contamination of the air environment [12].

Matrix tools can be defined as the primary method of analysis in the procedure of integrated environmental assessment of the territory for solving problems not only in the field of environmental safety, but also arising in the course of state land supervision or land cadastre, when choosing projects for land reclamation or conservation. It promotes reliable, clear and visual argumentation, the construction of a scientifically based and agreed point of view of experts, and also increases the conciseness of the information accepted for the development of appropriate software for automated environmental control systems.

Ecological territorial zoning as a methodological basis for effective state regulation actualizes the task of organizing a wider network of monitoring posts. This is due to the instability and dynamism of the business market environment, the focus of key development strategies on the constant diversification or expansion of production, increasing the level of utilization of reserve capacity, the use of new raw materials and construction materials. Rapid assessment of the level of technogenic load on residential neighborhoods of cities is still important from the point of view of harmonization of Russian and international standards for the organization of an environmental monitoring network based on the principles of Directive 2004/35/CE11 of the European Parliament.

The experience of the European Union shows that the organization of collective systems of environmental monitoring of urbanized territories is the first and indispensable step in preventing and minimizing regional local «ecological traces»:

- rational use of natural resources;
- recycle and reuse waste;
- prevent accidents and multiple rocket launches;
- maintain and restore biological diversity.

Social environmental responsibility of local enterprises meets a high level of public approval, increases business reputation and loyalty to the authorities.

3. Conclusion
So, the air environment is dynamic, toxicants emitted by numerous sources are found in any part of the city. The COVID-19 epidemic makes us recognize that the development of diagnostic tools for automated air monitoring systems in the aspect of zoning urbanized territory according to the criteria of "damage" and "level of localization of aerotechnogenic load” takes into account the sanitary and
hygienic component of monitoring in the implementation of regional programs and projects of sustainable development.

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