Information and measurement systems for environmental monitoring: a regional aspect

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Abstract. This article outlines the results of a study of information and measurement systems (IMS) used in monitoring the state of the environment in large urban agglomerations and their application using Krasnoyarsk Krai, Russian Federation, as an example. Additionally, it offers an analysis establishing the structure, constituent elements, as well as the effectiveness and efficiency of the use of IMS for monitoring the state of atmospheric air pollution in large urban agglomerations in the Krasnoyarsk Krai. The paper presents the results of observation and control over the state and degree of atmospheric air pollution for 2020 in the cities of Krasnoyarsk, Zelenogorsk, and Kansk. The problems that can be solved through application of automated IMS for monitoring the environmental situation in cities have been identified, specifying the challenges of using regional systems for monitoring the ecosystems of the territories of the Russian Federation. Additionally, the paper investigates the problem of the variety of automated IMS used in different regions of Russia to monitor the state of the environment in large urban agglomerations. The study identifies the prospects and features of further development of automated IMS for controlling and monitoring pollution and the state of the environment of urban agglomerations.

1. Introduction
In the modern days, environmental monitoring in large urban agglomerations is an integral part of the system for ensuring safe existence and development of cities and their population. It should be noted, however, that the development of information and measurement equipment and systems currently allows for comprehensive environmental monitoring through the use of sufficiently compact digital instruments with broad functionality [1]. It allows to approach monitoring of environmental state in a differentiated manner and to create automated multilevel system tracking adverse changes in the environment of urban settlements.

It should also be noted that the need to use information and measurement systems in cities is determined primarily by their high population density, large number of residents, and, as a result, the density of development of the territories. In addition, large-scale industrial production tends to be concentrated in urban areas, which adversely affects the environmental state of urban agglomerations.

We need to mention that in the Russian Federation, due to the great length of its territory, environmental monitoring issues are being addressed both at the federal level by implementation of general observation and monitoring of the environmental situation throughout the territory of the state, and at the regional level by each subject of the Federation, taking into account the characteristics of urban settlements. In fact, regional control and monitoring of the environment is the most efficient and
effective, as it is based on the specifics of each urban agglomeration, the peculiarities of its functioning and development in a certain area. Wherein processing, analysis and, correspondingly, reaction to negative changes of the environment will be immediate.

Thus, it seems relevant for us to explore the problems associated with regional aspects of operation of information and measurement systems in environmental monitoring in urban agglomerations.

1.1. Purpose of the study
The main purpose of our study is the research of information and measurement systems used in monitoring the state of the environment in large urban agglomerations and the results of their application using Krasnoyarsk Krai as an example.

1.2. Problem setup
The main problem addressed in our study is determination of efficiency and effectiveness of using information and measurement systems for monitoring the environmental situation in Krasnoyarsk Krai, a region of the Russian Federation.

1.3. Research questions
The study will provide answers to the following questions:

- Which environmental monitoring information and measurement systems are used by regions of the Russian Federation and what are their features?
- Which problems of environmental monitoring information and measurement systems exist in the Russian Federation and its regions?
- Which environmental monitoring system functions in the Krasnoyarsk Krai and what are its elements?
- What is the effectiveness of the subsystem monitoring the state of atmospheric air in the cities of Krasnoyarsk Krai?
- What are the prospects for using information and measurement systems in the process of environmental monitoring of the state of the environment in urban areas of the Russian Federation?

2. Research methods
The research methods used in our study are:

- theoretical (analysis of scientific literature, analysis and comparison of the results of monitoring the environmental situation using the territory of the Krasnoyarsk Krai as an example);
- empirical (observation, etc.).

3. Results and discussion
It is very important to understand that monitoring environmental state in large cities allows to control the state of the environment and, thus, to ensure the safe living conditions of the population in urban areas.

Moreover, in accordance with Russian legislation and departmental regulations, any production activity that affects the natural environment must be accompanied by environmental control and monitoring, allowing systematic monitoring of anthropogenic impacts, pollution, and the influence of such pollution on natural objects and the biosphere [2].

It should be noted that the larger the city, the more it needs an automated environmental monitoring system. We need to mention here that automated environmental monitoring systems are a set of technical and information and digital software tools that are designed for continuous (uninterrupted) monitoring and control of the environment in a specific area [3].
Accordingly, such an automated system should collect, store, organize and analyze the environmental state data received, determine the reasons for its negative change, and identify the sources of adverse impact on the environment, as well as determine the possibilities of reserve loads on the natural environment and its reserves for recovery [4].

In the Russian Federation, many regions containing urban agglomerations use complex differentiated automated environmental monitoring systems, the key elements of which are:

- radio transmitting and receiving systems operating at a certain distance;
- sensors monitoring the following environmental parameters: ambient temperature, concentrations of impurities and chemical elements in the air, water and soil;
- satellite communications and tracking systems associated with global positioning systems;
- specialized computing and telecommunications equipment and devices;
- specialized software, etc.

At the same time, automated environmental monitoring systems in large urban agglomerations should facilitate interconnection of natural data obtained in different areas of research to build and form a real picture of the ongoing environmental changes in order to develop strategic and operational management decisions that will ultimately ensure the safety of development and the existence of large urban agglomerations and their populations [5].

Thus, the use of automated information and measurement systems is primarily necessary for management and environmental agencies to ensure the safety and optimization of the environmental management process in large urban agglomerations. It should be noted here that modern information and measurement systems for monitoring the state of the environment allow to obtain the most complete information support of management and coordinating decisions in the field of protection and recovery of natural resources, ensure optimal integration of environmental information collected by various organizations and agencies, contribute to the development and improvement of calculation and analytical methods, as well as a comprehensive systemic assessment of the biosphere of large urban agglomerations.

In different regions of the Russian Federation, separate modules or projects of modules of monitoring geo-informational systems with limited functionalities have been developed and are being applied, which does not allow using them for other purposes or in other areas (territories). On the one hand, such system modules meet the requirements of the specific area in which they are used, and can also solve the issue of monitoring in one particular direction quite clearly. Which is definitely a plus. On the other hand, these modules are not universal and cannot be used in another environment and at another territory, limiting the possibilities for their perfection and development of multipurpose modular systems. Which is, of course, a minus.

Another problem of the regions of the Russian Federation in the field of environmental monitoring is the lack of a unified information and measurement system for rapid monitoring of natural and anthropogenic complexes. As a rule, there are rather disparate systems of operational or conditional operational control and monitoring of the state of the environment as a whole in a single system.

Moreover, this regional disparity makes impossible ensuring the availability of environmental monitoring data within the Russian Federation as a whole. In this regard, we believe it is necessary to highlight the importance of consolidating existing monitoring centers of collecting, processing and storing information such as remote land sensing, ground observation centers, etc. This issue is being resolved through the creation of a single observational center at the federal level for the collection, processing and storage of information from all regional sources (automated information and measurement systems). Such a center, when systematizing data from all regions of the Russian Federation, using modern cartographic and WEB technologies, will allow to make a uniform necessary assessment of the state of the natural environment in any point of the Russian Federation, including in each specific urban agglomeration, on-line and, consequently, to respond as efficiently and promptly as possible to all negative environmental changes in cities with the highest population density.
Taking into account the fact that the regions of the Russian Federation use different monitoring systems, we will list some of them.

For example, the Aero-Soft Information Technology Bureau, Ltd. has created an information and analysis system for environmental monitoring, which presents digital mechanisms for obtaining information from stationary points of constant control (territorial weather stations, hydrological shutters, etc.), departmental information systems, as well as from statistical sources and maps, information from which allows to assess the environmental situation in the region and to identify the causes for negative environmental changes. This system translates the information obtained from observation into geoinformation systems and creates environmental situation maps, which makes it possible to assess the environmental state at the level of a particular subject of the Federation where it is used [6]. Such a system is used, for example, in the Krasnodar Krai.

Of interest is the joint product of the "Prime Group" and "OTOIL" companies. This information and measurement system allows collecting information from stationary observation points at the enterprises, from hydrometeorological stations, and also takes into account information obtained through remote sensing of the Earth. On the basis of this data, the system analyzes the negative impact on the environment and even calculates payments that must be made to the budget for the negative impact on the environment by violators [7].

Considering the regional automated information and measurement systems, we should pay attention to the Krai system of environmental observations used at the Krasnoyarsk Krai territory. The key tasks of this system are:

- systematic monitoring of the state of the environment, including components of the natural environment, natural ecosystems in the region;
- systematic monitoring of their processes, events, phenomena, fluctuations in the parameters of environmental situation in the region;
- preservation, interpretation (generalization, analysis, structuring and systemization) of information about the parameters and components of the environment, its pollution at the territory of the region;
- providing interested public relations participants with current and urgent (operative) information on the state of the environment and its pollution.

Observations of the state and pollution of the environment are carried out using ground-based and remote methods.

The following components are currently operational within the system:

- air observation and control unit;
- surface water observation and control unit;
- surface soil cover observation and control unit;
- background radiation observation and control unit;
- seismic activity observation and control unit.

Thus, the information and measurement system used in the Krasnoyarsk Krai involves analysis of the main components of the ecosystem, such as air, water, soil, radiation and seismic background.

Further, we will consider the results of the use of an automated information measurement system for observation and control of atmospheric air, as the air quality is by far one of the main problems of urban agglomerations [8, 9].

For the analysis, it is necessary to list the indicators of the threshold limit values of pollutants in the atmosphere, set in accordance with the Decree of the Chief Sanitary Doctor of the Russian Federation of 22.12. 2017 No. 165, for urban and rural agglomerations, which we reproduced in table 1.
Taking into account these norms, it becomes possible to assess the operation of the air pollution control and monitoring system, which is included in the automated information and measurement monitoring system in the Krasnoyarsk Krai territory for 2020 in such urban agglomerations as Krasnoyarsk, Zelenogorsk, and Kansk.

For example, in the city of Krasnoyarsk, the level of pollution, taking into account the threshold limit values of harmful substances, was assessed as "very high" in January and February 2020, as "high" in March, April, May, June, July, August, September, and November 2020, and as "elevated" in October 2020. Moreover, the use of an automated information and measurement system for monitoring and controlling the air state made it possible to establish which harmful substances were present in the atmosphere of the city in excessive amounts. Figure 1 reflects the data.
Figure 1. The results of the operation of the automated information and measurement system for monitoring atmospheric air pollution in Krasnoyarsk for 2020.

Thus, we see a significant excess of the threshold limit value for formaldehyde in the atmospheric air of Krasnoyarsk. We need to note here that formaldehyde is the strongest carcinogen, it acts as a fast-acting cell poison and has a high class of danger to the population [10]. It should be noted that in the case of its increased concentration in the air there is a sufficiently pronounced, sharp and strong technical smell.

It is important to understand that detecting an increased concentration of formaldehyde in the air can prevent many negative effects of this substance on humans. And of course, analyzing the composition of atmospheric air is possible only through automated information and measurement systems.

In another major city in the Krasnoyarsk Krai, Zelenogorsk, the level of pollution, taking into account the threshold limit values of harmful substances, was assessed as "elevated" in February, May, and September 2020, and in the remaining months of 2020 it was described as "low". The use of an automated information and measurement system for monitoring and controlling the air state made it possible to establish which harmful substances were present in the atmosphere of the city in excessive amounts and by what percentage they exceeded the threshold. Figure 2 reflects the data.

Figure 2. The results of the operation of the automated information and measurement system for monitoring atmospheric air pollution in Zelenogorsk for 2020.
Also of interest are the data on the city of Kansk in the Krasnoyarsk Krai, the level of pollution, taking into account the threshold limit values of harmful substances, was assessed as "elevated" in February, March, April, May and November 2020; in the remaining months of 2020 it was characterized as "low." The use of an automated information and measurement system for monitoring and controlling the air state also revealed which harmful substances were present in the city's atmosphere in excessive amounts and by what percentage they exceeded the threshold. Figure 3 reflects the data.

![Figure 3. The results of the operation of the automated information and measurement system for monitoring atmospheric air pollution in Kansk for 2020.](image)

Analyzing the results of using an automated information and measurement system for controlling and monitoring atmospheric air in the cities of Zelenogorsk and Kansk, we should note that the excess of the threshold limit values is established for airborne particles and nitrogen oxide.

It should be pointed out here that the airborne particles are a widespread air pollutant that contains a mixture of solid and liquid particles in the air in a suspended state. These particles themselves pose a very serious threat to the health of residents of large urban agglomerations because they penetrate deep into the lungs and settle there. Being in the air, which the population of large urban agglomerations breathes, they worsen the health of the population and, in turn, facilitate the increase in respiratory and cardiovascular diseases, as well as affect other health indicators [11]. There is no evidence of a safe level of airborne particle, with concentrations below which not affecting human health [12, 13]. This confirms the importance of identifying suspended particles in the atmosphere.

Thus, even the data from the atmospheric air information and measurement systems, which is part of the overall automated system of information and measurement observation and control of the Krasnoyarsk Krai, confirm the value and importance of such automated environmental control systems functioning.

Considering the prospects for the further development of such automated systems of information and measurement monitoring of environmental quality in urban agglomerations, it should be noted that in the future they will become even more necessary, as the density of buildings and the population numbers of large urban agglomerations is steadily increasing, the number of industrial and other enterprises and organizations having a negative impact on the environment is growing, while environmental resources are rapidly depleting.

Accordingly, the more accurate and better the automated information and measurement system for monitoring the environmental situation in cities operates and is used, the more correct and timely management decisions can be made to prevent environmental disasters.

Undoubtedly, environmentally secure future of cities cannot be imagined without such measuring and monitoring systems [14, 15].
4. Conclusions
The following conclusions can be drawn from our study:

- In the Russian Federation, given its great length and specific features, each entity uses its own automated system of information and measurement monitoring of the environmental situation on its territory, which on the one hand ensures the effective use of such systems in a particular territory, and on the other hand determines the lack of uniformity and absence of a unified data collection system.
- Automated systems for information and measurement monitoring of the environmental situation include integrated subsystems for monitoring and controlling atmospheric air, surface water, soil, radiation and seismic background.
- As a result of the use of automated information and measurement systems for environmental monitoring in large urban agglomerations, institutions, organizations and the public receive the necessary information on the state of the environment, which allows them to make timely management decisions and introduce corrective measures to preserve the environment and its resources.
- Since the negative impact on the environment of urban agglomerations is primarily exerted by enterprises and industrial complex, it is important to improve and implement automated information and measurement systems of these facilities.
- In the future, we believe that the development and differentiation of automated systems of information and measurement monitoring of the environmental situation in urban agglomerations will increase its pace, as the growth of large cities is very rapid.

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