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Problems of operational control of physical and chemical environmental factors in residential areas of Russian settlements

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Abstract. The formation of human life conditions in residential areas depends on the state of ecological balance in these territories, which, in turn, relays the influence of various natural and anthropogenic environmental factors. From a practical point of view, this influence is increasingly becoming cumulative or even complex. The article discusses the need to create a system of integrated (aggregate) monitoring of residential areas, providing visualization of predictive estimates of the spread of pollution. To solve such a problem, it is necessary to develop a theoretical model (concept) of complex (aggregate, generalized) monitoring of the ecological situation. This approach is based on the use of the principle of combining data on the nature and parameters of the main air pollutants, infra- and ultrasonic, as well as electromagnetic radiation, vibrations, meteorological parameters and the structure of landscape features of the zone. Modern automated monitoring systems of natural and technogenic areas are considered. Their advantages and disadvantages are noted. It is concluded that a system is necessary to develop, which solves a wider range of tasks.

1 Introduction

Despite the fact that total life expectancy in the Russian Federation has increased slightly, a high mortality rate still remains due to various diseases. One of the main causes of high mortality is the unsatisfactory state of health of the population, which, according to WHO, depends on the state of the environment by 20-30%.

The program of action "Agenda 21", adopted at the UN Conference in Rio de Janeiro in 1992, noted that all states need to have programs to identify environmental factors that threaten health and reduce the associated risks [1]. The currently existing systems for monitoring the state of the environment in residential areas constantly control only meteorological parameters. The noise levels of the sound range and the content of harmful substances in the atmospheric air are determined only periodically or occasionally. Measurements of soil contamination are independent. The levels of infrasound and ultrasound, vibrations, electromagnetic radiation are practically not measured. The development of a unified system of operational control of physical and chemical

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environmental factors in residential areas of settlements is a vital necessity, since it can significantly reduce the risks of impact of physical and chemical factors on human health.

The effect of polluting factors on the condition of residential areas, on biota and, ultimately, on human health is undeniable. Among the reasons that have a negative impact on the health of the population and the demographic situation, the environmental component plays a significant role. According to the data of the State Environmental Monitoring Service, the levels of environmental pollution in recent years have generally remained high, not adequate to the industrial recession (see, for example, [2], etc.).

The problem outlined in this work is important almost throughout the entire territory of the Russian Federation, since the level of such pollution and the recorded diseases caused by these pollutions are high all-over Russia.

2 General state of the environmental pollution problems

The problem of human impact on the environment and the reverse effect of the environment on people nowadays is becoming increasingly important ([3], etc.).

Anthropogenic impact in cities is one of the essential issues of fundamental and applied importance. Its results determine the state of the urban environment. An unfavorable environmental situation is formed in a modern city as a result of the development of industry, transport, and the rapid growth of the urban area.

The remaining natural ecosystems are not capable to compensate for the negative impact of anthropogenic factors, meanwhile the actual administrative measures taken only partially restrain the growth of the aggressive impact of household, transport and industrial waste on the human environment in the city. The study of these issues is part of the range of problems of interest to scientists and practical specialists [2, 4, 5].

2.1 Air and soil pollution

Air contamination continues to be one of the main risk factors for public health.

Dust, nitrogen oxides, carbon monoxide, formaldehyde, hydrocarbons, and sulfur dioxide remain priority air pollutants. In a number of regions of Russia, in areas of the active motor transport traffic, the excess of the MPC level in terms of the number of samples containing nitrogen oxides and carbon in the atmospheric air above the MPC, reaches up to 60%. Along with this, in recent years, the number of samples exceeding the MPC for benzopyrene, an extremely toxic substance, has been increasing. Including, the influence of these pollutants leads to the fact that chronic diseases of the respiratory system are becoming more common among children and adolescents [2].

There is a contamination of the soil of residential areas according to sanitary and chemical indicators. In a number of territories, the growth of samples significantly exceeding the permissible levels of contamination continues to be noted. In addition to the contamination of residential areas with lead and cadmium compounds, in the locations of highways with active traffic, the underlying surface is saturated with solid carbon compounds and liquid-drop unburned fractions of hydrocarbons. As shown in [6], the level of average monthly single concentrations of pollutants such as carbon monoxide, suspended particles, soot, can increase by 3-5 times, depending on changes in climatic conditions. The concentrations of the main pollutants (sulfur dioxide, etc.) most often exceed the permissible levels in many cities of Russia [7-9].

Other pollutants also pose a significant danger to humans. Thus, according to the data of the State Budgetary Institution "Mosecomonitoring" on the territory of Moscow near major highways, there is a steady (within 6%) annual growth of the maximum observed average annual concentrations of fine suspended particles with a size of less than 10 microns: 2004

– 0,045 mg/m^3, 2005 – 0,046 mg/m^3, 2006 – 0,049 mg/m^3. Since 2004, there has been a tendency for a steady increase in nitrogen dioxide pollution (3-5% per year). At the same time, the growth in nitrogen dioxide content was also detected in the residential areas of the city [10]. In almost all districts of St. Petersburg, there is an excess of MPC levels by gaseous pollutants. So, according to data for 2008, there was an excess of permissible levels: nitrogen dioxide 1.6 MPC, benzopyrene 1.4-3.5 MPC, ozone up to 2.5 MPC, formaldehyde 1.3-3 MPC, ammonia 3.5-7.9 MPC [7].

Since these major cities are among those in which (due to their «metropolitan status") significant attention is paid to environmental protection, it can be concluded that the situation in large, medium and small industrial cities may be even more difficult.

A large number of works are devoted to the analysis of the influence of pollutants on human health. Thus, in Ulan-Ude, more than a quarter (28%) of the population lives in areas with an unacceptable risk of developing cancer. The high content of suspended and gaseous substances in the atmosphere is associated with 12% of all diseases and 15.5% of deaths of the city's population [11].

According to the results of the analysis in Ivanovo, there is an excess of permissible levels: benzopyrene 1.4 MPC, formaldehyde 4.6 MPC, suspended substances 1.4 MPC [12].

The situation is similar in other industrial cities. In many works devoted to the study of this problem, there is a need to improve the air quality control system, optimize and enhance measurement methods, increase the number of observation posts, etc. [11-13].

Pollutants have a large impact on agricultural soils, which also affects food products of plant and animal origin via the food chains [14-19].

2.2 Electromagnetic smog in the technosphere

Studies show an increase in EMR levels in residential areas [20]. So, if the results of the analysis of the situation in Minsk in the territories adjacent to radio engineering facilities and in residential areas located near sources of low-frequency electromagnetic fields (LF EMF) for the period from 2001 to 2003 revealed a slight tendency (in terms of electromagnetic field strength by 1-2 V/m, in terms of power flux density by 0.1–1.2 μW/cm^2) of increase of the levels of electromagnetic fields without exceeding the existing maximum permission level, meantime an excess of the recommended safe level of 0.2 μT is noted at a distance of 20 m from the sources in the conditions of old buildings.

A significant increase in the level of EMF is also observed in the residential areas [21-22]. The data obtained indicate the influence of the increasing number of electronic equipment on the level of EMF. Such influence also extends to medical institutions, as well as children's institutions [23].

A significant contribution to the increase in the level of EMR is also made by the fact that in a substantial part of residential or office buildings there is no grounding required by modern standards (currently, the Rules for the installation of electrical equipment provide for three-wire power supply systems as TN-S and TN-C-S, but in many houses of old construction there is an older two-wire system). As the research results show [24-26], even a simple addition of a two-wire power supply system in an apartment with a grounding wire significantly reduces the levels of EMF. Since the reduction of EMF levels is a significant task, it is necessary to develop an appropriate monitoring system.

2.3 Acoustic and noise pollution of the technosphere

From the point of view of the influence on the human condition, a significant problem is the impact of acoustic, in particular infrared and ultrasonic, signals. Numerous studies indicate that high-intensity noise has a harmful effect on the human body: the rhythm of heart activity changes, blood pressure increases, hearing deteriorates, the process of fatigue accelerates, and physical and psychological reactions slow down. Noise reduces the efficiency of mental work by 60 %, and physical work by 30 %. With an increase in the noise level from 70 to 90 dB, labor productivity decreases by 20 %.

Hearing disorders caused by intense noise occupy the first place in the all-Russian structure of occupational diseases of the ENT organs (54.8%) [27]. In large cities, the average traffic intensity reaches 2000-3000 transport units per hour or even more, and the maximum noise levels are about 90-95 dBA. Small cities are not exceptions, where traffic load has sharply increased in recent years. Recently, the average noise level produced by transport has increased by 12-14 dBA. For example, the authors of the study in Murom revealed the traffic intensity at some intersections up to 11,300 units per day (an average of 470 per hour) with a noise level of more than 100 dBA [28-29]. Noise that occurs on the roadway of the highway extends not only to the adjacent territory, but also deep into the residential area.

Acoustic signals include infra-and ultrasonic vibrations. It is known that the impact of vibrations with a frequency of 2–15 Hz and an intensity of 95–105 dB causes a slowdown in visual reaction, increases the number of tracking errors for measuring devices, disrupts the functions of the vestibular apparatus, and changes the rhythm of cardiac activity and respiration. The measured levels of intensity of infrasonic components in the spectrum for a number of industrial sources (frequency / intensity) are equal: gas turbine units 2–6 Hz / 120–133 dB, trucks (exhaust) - 2–32 Hz / 117–128 dB, industrial blowers - 3 –12 Hz / 110–130 dB, etc. [30-31].

The impact of vibrations merges with the influence of infrasonic vibrations. In addition to the understandable impact on the load-bearing structures of mechanical systems, foundations and walls of buildings, vibrations also affect the human body. It is known that the human body has its own resonant frequencies that have values, for example, for the head-20-30 Hz, eyes-40-100 Hz, heart-4-6 Hz, spine-4-6 Hz, etc. [32].

2.4 Impact of macro- and microclimate on the environment

Climate change has a significant impact on the life of a technogenic zone, that is why the analysis of the nature and levels of pollution in many cases is impossible without taking into account the influence of urbanization on local or regional climatic conditions, since cities create a specific climate within themselves, which occurs under the influence of pollution itself. Under the influence of dynamic man-made activity, as well as the transfer of various pollutants from residential and industrial areas, the climate of the city changes not only locally, but also on a regional scale, and globally in the case of megacities [33]. As a consequence, the task of combining environmental monitoring with meteorological monitoring becomes relevant.

The control of meteorological parameters is performed at special meteorological stations, and the measurement results are considered average for this territory [34-35]. However, each of the specific areas of the city has its own climatic features, which can change, and fundamentally, some of the parameters that affect the nature of localization or propagation of noise [36-39]. First of all, these parameters include the wind speed and direction, as well as the air temperature and its distribution in the horizontal and vertical planes. Meteorological parameters, such as atmospheric pressure and humidity, and the amount of liquid precipitation, also have a significant impact on the distribution of the pollutants discussed above. For instance, high humidity in the atmosphere reduces the intensity of ultra- and infrasound; raised humidity of soils and building structures, due to precipitation, increases the degree of vibration damping, etc.

3 Modern automated monitoring systems for natural and technogenic zones

The creation of automated monitoring systems for natural and technogenic zones is currently an actual task. In relation to different monitoring tasks (meteorological or environmental), this task was solved in different ways [40-44]. As the analysis of this information shows, the construction of such systems has a number of general principles that are implemented through well-known technical solutions. At the same time, taking into account the specific features of the construction of the control and measurement system itself, the tasks to be solved, the structure of the system will have its own characteristics.

Visualization of monitoring results (the level of pollution, the state of the environment and other observation parameters) is clearly carried out by means of geoinformation systems (GIS). Both commercial (ArcInfo, MapInfo, Panorama, Ingeo) and freely distributed GIS (Quantum GIS, vSIG) are successfully used for this purpose. One of the advantages of using GIS is the ability to link observational data to a cartographic basis. This allows us to consider the spatial distribution of the phenomena under study and to carry out mathematical modeling [45-51].

Thus, the development of methods and tools for residential areas monitoring that provide a comprehensive analysis of the impact of various physical and chemical parameters is an urgent task.

Currently, there are the monitoring systems that provide monitoring the totality of environmental parameters and visualization of the data obtained. For example, among such systems, one can mention the system of ecological monitoring of the environment "SAMOS" [52]. The system performs continuous, round-the-clock, automated monitoring of the state of the environment and provides timely and reliable information to responsible persons for making effective management decisions in the field of environmental protection and pollution monitoring. However, it should be noted that, despite a number of absolute advantages, the system does not allow monitoring and forecasting the propagation of acoustic noise and electromagnetic pollution.

Also, the complex of automation tools "Joint Center of Operative Response" (ECOR) is known [53, 54]. This system provides solutions to a number of issues within the "Safe City" program in the following categories: the population and municipal infrastructure safety (public safety, protection from emergencies, fires, etc.); transport safety (including traffic flow management); environmental safety; coordination and interaction of all system structures. It should be noted that the system is mainly aimed at solving the tasks of general control of law and order, including transport management in emergency situations. The tasks of ecology in this system occupy a secondary place and are primarily related to the control of hydrometeorological information, including warnings about floods, inundations, etc.

The environmental monitoring system (SiMPOS) The Environmental monitoring system (SiMPOS) is positioned as a universal, multifunctional system designed for operational control of the main environmental parameters [55]. However, it is basically designed to solve specific tasks of the Ministry of Emergency Situations.

The system of the State Environmental Budgetary Institution "Mosekomonitoring" is one of the most developed monitoring systems [56]. The formation of the system dates back to the beginning of the 21st century [57-58]. The main task of the system is to carry out environmental monitoring on the territory of the city of Moscow.

The system provides data acquisition and visualization in the main areas of monitoring: atmospheric air; surface water objects; soils; green spaces; groundwater quality; landslide processes; noise levels [59]. The system provides to solve tasks of monitoring and visualization of the main parameters of environmental pollution in a large city. At the same

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time, there is no information about the possibility of monitoring the noise level in the infrasonic part of the range, as well as the level of electromagnetic smog is not controlled.

In general, we can say that all the systems considered above do not take into account the presence of electromagnetic smog (pollution) in the urban environment, the influence of acoustic noise in the infrasound band, the lack of predicting the propagation of acoustic noise deep into the residential area, as well as the possibility of karst activity in the city.

4 Conclusion

The identification of the relationship and co-influence of the indicated parameters on the nature of the environmental situation refers to fundamental problems. It is impossible to solve such a fundamental problem without the use of appropriate equipment, that sets the task of developing and building an information and measurement system for receiving, processing and presenting data.

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