Environmental Quality Assessment of Urban Areas Using Geoinformation Technologies (on Example of the Cities of Central Russia)

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Abstract. On the example of the urbanized territories of Central Russia (the cities of Voronezh, Lipetsk, Kursk, Belgorod, Tambov and others) geocological aspects of environmental quality are considered. The content of anthropogenic pollutants in natural environments has been estimated. In the GIS environment, the levels of environmental risk for the population of large cities are calculated. A comprehensive geocological zoning of the studied urbanized territories was carried out. Based on geoinformation technologies, a scheme of environmental and geochemical monitoring of an industrialized city has been developed.

1. Introduction

The development of the intellectual and technological progress entails a significant increase in the comfort and quality of life. However, along with this, there is a constantly increasing technogenic “pressure” on the environment, which inevitably leads to an increase in anthropogenic pollutants in natural objects and the level of environmental risk for the population of industrial cities [1, 2, 3, 4]. In Russia and most other developed countries of the world, this problem has escalated since the mid-20th century at high rates of development of industry, oil production and oil refining industries, due to an increase in the capacity of heat power enterprises (TPS, TPP, etc), motor vehicles etc. Against the background of increasing geochemical pollution of the habitat, the population of many large cities shows ecologically caused diseases, which causes increased attention of scientists and environmental practitioners to study the mechanisms of formation of technogenic pollution zones and to search for effective ways to improve the urban environment [1].

These problems are relevant for many cities of Russia and other developed countries of the world. Most of the studied urbanized territories have a complex architectural and planning structure of urban development and an increased transport load, which serves as a prerequisite for the formation of zones of geochemical pollution of natural objects and a decrease in geocological comfort for the living population [1, 5, 6].

The main mechanism for assessing the environmental quality of urbanized territories is ecological and geochemical monitoring based on geoinformation technologies [6, 7, 8, 9]. So, on the example of the urban district of the city of Voronezh, environmental and geochemical monitoring is a multifunctional subsystem that interacts with other subsystems of a unified state system of environmental monitoring. An analysis of the available information allows us to affirm that the incidence rates of the population for various classes of diseases can serve as indicators of environmental quality. For example, an increase in cancer incidence in the population can serve as an indicator of air pollution and soil cover by lead, increase in the incidence of diseases of the nervous system and sensory organs in the child population. An indicator of the increase in the content of sulfur oxide, nitrogen, formaldehyde in the atmosphere may be an increase in the incidence of respiratory diseases in the population [10, 11, 12].

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The relevance of this problem is enhanced by the fact that today in Russia there is no single organizationally formed system for collecting information and methods for interlinking data from various departmental structures, which may serve as the subject of further developments in the field of GIS technologies.

2. Equipment and devices used in studies

Ecological and geochemical monitoring of an industrialized city based on GIS technology is [9]:
- a system of observations of changes in the geochemical composition of the main natural environments - soil and atmosphere under the influence of technogenic pressure, as well as under the influence of urban planning and aeration factors of environmental risk;
- health monitoring system as a “response of the environment” to the content of environmental pollutants;
- development of measures to improve the natural environment of the city and minimize environmental risk.

The tasks of ecological and geochemical monitoring of an industrialized city based on GIS technologies are:
- control of the content of various pollutants in the deposit environments of the city;
- timely detection of changes in the content of pollutants in natural environments - soil and atmosphere; assessment and forecast of pollution dynamics;
- calculation of environmental risk levels, and forecasting the occurrence of environmentally-caused diseases of the population;
- identification of environmentally-related diseases in the population;
- identification of priority technogenic, urban planning, meteorological factors of environmental pollution of the city;
- the detailed analysis of the emissions register of industrial enterprises, especially the analysis of emissions of specific little-studied pollution ingredients of various environments;
- forecast and development of recommendations on the prevention, elimination of the consequences of the negative impact of environmental pollution on the human body;
- information support of environmental services of environmental control and health authorities with the results of exploratory studies on health risk assessment and spatial distribution of risk zones;
- creation of cartographic material based on GIS technologies, including the data obtained for further use of the analysis results in the environment-health system by various planning and design, environmental, medical and other services.

The main goal of creating an environmental-geochemical monitoring system for urbanized territories is to organize, on the basis of geoinformation technologies, an intersectoral and hierarchical system of collecting, processing, storing and issuing information that provides continuous diagnosis of public health and the environment. Also information support for decision-making aimed at ensuring environmental-hygienic well-being [5, 9].

Our environmental and geochemical monitoring of the urbanized territories of the cities of Central Russia (Voronezh, Lipetsk, Kursk, Belgorod, Tambov and others) is carried out on the basis of the author's GIS "Ecological and socio-economic conditions of urbanized territories of Central Russia", which includes a database of environmental pollution for long period, morbidity of the population of various age groups, socio-economic and microclimatic conditions. Cartographic and landscape-planning blocks of GIS data allow you to objectively assess the situation at the moment, predict its further development and provide an opportunity to analyze and display the condition of urban ecosystems, including public health [5, 9].

GIS maps constitute the basis of documents for analysis of the possible impact on the population of various environmental pollution factors, as morbidity of the population serves as a “response” of the environment to the impact of anthropogenic pressure [9].

As part of the ecological and geochemical GIS block, a planned analysis of samples of atmospheric air, soil and drinking water is carried out.

In a planned analysis of the pollutant content in atmospheric air, it is necessary to carry out point route sampling of air samples at equally equidistant points in similar climatic conditions. The frequency of selection and distance between points depends on the ecological and functional zone of the city (table 1).
Table 1. Sampling of atmospheric air in various ecological and functional zones of the cities of Central Russia

| Ecological and functional area          | Equidistance of air sampling points, km | Sampling frequency per year |
|----------------------------------------|----------------------------------------|-----------------------------|
| industrial                             | 0.5                                    | 8                           |
| residential, public and business       | 1                                      | 4                           |
| recreational                           | 2                                      | 2                           |

The analysis of the content of atmospheric pollutants characteristic of the study area is carried out in the selected air samples. For the studied cities of Central Russia - carbon monoxide (II), sulfur oxide (IV), nitric oxide (IV), formaldehyde, dust and lead.

In a planned study of soil pollution once a year, soil samples are taken at points equidistant at 2 km where there is no soil brought in or soil brought in has been at this point for more than 10 years. The optimal time for sampling is the spring period after snow melts.

It is necessary to regularly determine the content of oil products and heavy metals in the selected samples.

As part of the environmental-medical unit, statistical information is collected on the incidence of the population of various ages of cities of Central Russia for the main classes of diseases in therapeutic and pediatric areas.

Ecological-geochemical and ecological-medical units are an integral part of the automated database “Ecogeochemistry and public health in the cities of Central Russia”. The creation of this database is carried out by means of the MS Excel software package, by far the most optimal for the implementation of the tasks. The database contains information on the content of atmospheric and soil pollutants with a specific indication of the date and address of sampling points. For air sampling points, microclimatic indicators are also indicated - air temperature, relative humidity, atmospheric pressure, wind direction and speed.

Within the database “Ecogeochemistry and Public Health of Voronezh”, the values of the atmospheric pollution index, the total soil pollution index, the carcinogenic and non-carcinogenic environmental risks for each sampling point, as well as the average indicators for the regions and the city are calculated.

As part of the geographic cartographic block, the city’s cartographic material is updated annually, and new residential facilities, construction projects that have begun, as well as environmental risk facilities - gas stations, industrial facilities, highways, etc. — are printed on an electronic map. In addition, an increase or decrease in the recreational area, green spaces, gardens, parks, etc., is recorded on an electronic map.

In addition, within this block, it is necessary to collect annual statistical information on environmental-meteorological and climatic data — air temperature, relative humidity, atmospheric pressure, wind speed and direction in different areas of the city, as well as in different quarters with multi-storey buildings.

Thus, the main components of the GIS “Ecological and socio-economic conditions of the urbanized territories of Central Russia”, through which environmental and geochemical monitoring is carried out, are the automated database “Ecogeochemistry and public health of the cities of Central Russia” and the geographic cartographic unit.

3. Results and Discussion

Analyzing the atmospheric pollution of the cities of Central Russia, it seems possible to conclude that the priority contribution of motor emissions to the formation of geochemical pollution fields. In addition, the relief of the territory makes a significant contribution to air pollution. So, on the territory of the urban district of the city of Voronezh, the highest pollution of the atmosphere is in the area of the Chernavsky bridge (the intersection of St. Razin St., Manezhnaya St.). The reason for the high air pollution in this area is the large number of vehicles passing through this intersection. In addition, this territory is located in the impact zone of Municipal Unitary Enterprise “Voronezhteploset”, which
belongs to hazard class 1, which contributes to the formation of pollution in this section of the city of Voronezh (fig. 1).

Also, the contaminated territory is located in the Mashmet microdistrict of the Left Bank district of Voronezh. Pollution of this territory is formed by industrial enterprises of the city, as well as motor vehicles, the movement of which is often hampered by traffic jams in the vicinity of the Mashmet railway station (fig. 1).

Another important factor in air pollution is aeration. For example, the formation of air pollution in the Zheleznodorozhny district of the city of Voronezh can be explained by microclimatic conditions - atmospheric transport of pollutants from the industrial zone of the Kominternovsky district of Voronezh, located on the windward side to the Zheleznodorozhny administrative region of Voronezh (fig. 1).

The atmosphere of the microdistrict of the Agricultural Institute of the Central District and the Northern Microdistrict is least polluted. You can also call “clean” the atmosphere of the urban outskirts - Regional Hospital, village Shilovo, village Nikolskoye and others. Low atmospheric pollution is observed in parts of the Sovietsky administrative district of Voronezh (38 Marshak St.), remote from the industrial and transport zone.

In the immediate vicinity of the polluted territories, there are “clean” zones in the Central and Leninsky district of the city, the so-called “Quiet Center”, an example of which is the territory in the area of the Pokrovskaya Church (figure 1).

The formation of zones with low atmospheric pollution is due to the remoteness of these territories from the industrial and transport zones of the city or to the location on the windward side of those, as well as the features of the microclimate and aeration mode.

Analyzing soil pollution, it seems possible to draw conclusions about the general environmental pollution of the cities of Central Russia over a long period.

Thus, an analysis of pollution of the soil cover of the city of Voronezh with heavy metals and oil products showed that the highest concentrations of this pollutant are observed in the left-bank part of the city. Abnormal concentrations of petroleum products in the soil were found in the oil depot area, as well as in the Mashmet microdistrict of the left-bank district of the city (the zone of influence of industrial enterprises of synthetic rubber and tire production). Zones of high soil pollution with oil products are also observed along major transport highways of the city of Voronezh - st. Dimitrov, st. Ostuzhev, Moscow Avenue, st. Voroshilov, st. Krasnoznamyanaya and others. Relatively clean zones, the concentration of oil products in which is less than 400 mg / kg, are observed in the Northern microdistrict of the Kominternovsky district, the microdistrict of the Agricultural Institute of the Central District, as well as in some parts of the Central Administrative Region where there is no heavy traffic. Thus, oil pollution of the soil is directly proportional to the average speed of vehicles, the traffic congestion located near the sampling points.

Studying the environmental risk of chronic diseases of the blood and cardiovascular system, the factor of which is carbon monoxide (carbon monoxide II), several sites with a very high level of risk were identified, with a total area of 0.6 km², the largest of which is located in st. Dimitrov, Voronezh.

Nearly all the major transport arteries of the cities of Central Russia and at major intersections, a high-risk zone.

In the cold season, in most cities studied, the level of non-cancerogenic risk of diseases when exposed to carbon monoxide II decreases. However, at some intersections of highways there is a tendency to increase, due to an increase of the traffic congestion with changing climatic conditions.

Analyzing the environmental risk of respiratory and blood diseases when exposed to nitrogen dioxide, high-risk areas with a total area of 5.8 km² and very high risk with a total area of 2.5 km² were identified. The location of these zones in the area of the Voronezh-1 railway station affects residential areas from the private sector in the coastal zone of the Voronezh reservoir to the post-war buildings of the Kominternovsky district.

The most negative situation is when assessing the non-carcinogenic risk of respiratory diseases, eye diseases, decreased immunity when exposed to formaldehyde.

In the warm season, more than 50% of the territory of the studied cities of Central Russia is located in a zone of a very high risk level. In the cold season, the territory of increased, high and very high risk level occupies about 70% of urban space.

By calculating the integral non-carcinogenic risk of chronic diseases (HI), significant differentiations of this indicator within the same urbanized area were established.
Figure 1. Geoinformational zoning of the territory of the urban district of the city of Voronezh in terms of the integral indicator of atmospheric pollution

For example, on the territory of the urban district of the city of Voronezh, the zones of high and very high non-carcinogenic risk of chronic diseases are located in the Zheleznodorozhny district of the city, the Mashmet microdistrict of the Left Bank region, Sovetsky district and in the area of st.
Transportnaya Central District (fig. 2). High-risk territory is observed mainly in the left-bank and central parts of the city (figure 2).

Figure 2. GIS map of the total level of non-carcinogenic risk (HI) in the urban district of the city of Voronezh during the warm season
The low-risk zone is located mainly in the northern part of the city (the Northern microdistrict of the Kominternovsky district and the microdistrict of the Agricultural Institute of the Central District of Voronezh).

In the cold season, a similar situation is observed, with the exception of a significant reduction in areas of increased, high and very high risk levels.

4. Conclusion

Thus, the developed scheme of ecological and geochemical monitoring of an industrialized city based on geoinformation technologies can be implemented in most industrial cities of Russia and other developed countries of the world. However, it is necessary to take into account the specifics of the technogenic load and the environmental conditions of a particular city in order to compile a priority list of the studied environmental pollutants and public health criteria.

An analysis of the formation of fields of ecological and geochemical pollution of urban areas of the cities of Central Russia showed the priority of road emissions compared with industrial and energy enterprises.

In addition to environmental factors, microclimatic and socio-economic conditions of the territory contribute to the formation of environmental risk zones and lower geo-ecological comfort.

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