The Study of the Environmental Risk of Urban Areas on the Example of the City of Voronezh

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Abstract. Studied the regularity of formation of socio-environmental conditions that affect the environmental safety of cities on the example of the city of Voronezh. The results obtained in the course of many years of monitoring studies are summarized in the GIS "Environmental and socio-economic conditions of the city of Voronezh". GIS consists of a system of hierarchically subdivided sections of databases and thematic mapping tools, reflecting the natural resource potential, socio-economic and environmental-hygienic situation of urbanized territories. The basis is Earth remote sensing data, and official statistics from environmental agencies. For mathematical cartographic modeling, an array of official statistical information was selected for a 20-year period, from 1998 to 2018.

1. Introduction
In the XX-XXI centuries, in Russia, as in most other countries of the world, against the background of industrialization and the development of technical potential, there has been a significant increase in the well-being of the population. Along with this, cities become centers of acute social and environmental problems caused by the work of industry and the functioning of transport [1, 2, 3, 4].

Currently, the consequence of these problems is the emergence of environmentally caused diseases in the population living in large industrial cities. This fact causes increased attention among scientists and managers and causes a comprehensive study of this problem, as well as a search for ways to improve the environmental safety of cities. Conducting modern monitoring studies of environmental quality requires the processing of large arrays of data from many years of research, which entails the need to use modern geographic information technologies [2, 3, 4].

Thus, the aim of the project is to study the regularity of formation of socio-environmental conditions that affect the environmental safety of cities on the example of the city of Voronezh.

In the XX century, the main sources of environmental pollution in large cities were fuel and industrial enterprises. However, in the XXI century the situation has changed a lot. In most countries of the world, environmental legislation has been tightened, which has reduced anthropogenic pollution by industrial enterprises. At the same time, an increase in the well-being of citizens led to an increase in the number of personal vehicles. As a result, roads designed back in the 20th century cannot cope with the load [5, 6, 7].

Thus, at present, motor transport is becoming the main source of urban air pollution. So, in the city of Voronezh, motor vehicle emissions account for more than 90% of all anthropogenic pollution [6].

In addition, a negative factor is that in developing countries, most of the vehicles are cars older than 10 years that emit significantly more pollution into the environment. In Russia, this problem was successfully resolved in 2010-2011 [6].

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2. Equipment and devices used in studies

The results obtained in the course of many years of monitoring studies are summarized in the GIS "Environmental and socio-economic conditions of the city of Voronezh". GIS consists of a system of hierarchically subdivided sections of databases and thematic mapping tools, reflecting the natural resource potential, socio-economic and environmental-hygienic situation of urbanized territories [6].

The basis is Earth remote sensing data, and official statistics from environmental agencies. Information was collected to characterize the functional planning structure and landscape and environmental conditions for model regions on the basis of special field studies, stock processing material, including cartographic, from regional integrated and sectoral environmental agencies. For mathematical cartographic modeling, an array of official statistical information was selected for a 20-year period, from 1998 to 2018 [6].

The developed geoinformation resources providing monitoring studies of social and environmental conditions for the population, implemented as part of the GIS, contain 4 sections.

1. Section "Natural Potential".
2. Section "Microclimatic conditions".
3. Section "Socio-environmental conditions."
4. Section Model "Ecological safety of the population."

Based on GIS-maps, a set of environmental-designing measures is being developed to increase the integral indicator of the environmental safety of the population in a particular urbanized area.

Currently, in Russia and in the world there are various approaches to assessing environmental risk for the population living in industrialized cities [8, 9, 10, 11, 12, 13].

In Russia, the most widely used methodology belongs to the Center for Hygiene named after Erisman, based on the calculation of carcinogenic and non-carcinogenic risks. The methodology determines the effect of each atmospheric pollutant on various systems and organs of a person and by comparing the concentration with a safe dose, the probability of the occurrence of various environmentally caused diseases for a particular territory is determined.

The environmental risk assessment methodology developed by Professor V. Privalenko is also widely used. It is based on determining the environmental hazard of a territory depending on the content in the atmosphere and soil of different pollutants, taking into account their degree of danger for the population (formula 1).

\[
Dg = \left[ k1 \left( \sum_{i=1}^{n} \frac{C_{n}}{C_{ph}} \right) + \left( \sum_{i=1}^{m} \frac{C_{m}}{C_{ph}} \right) + \left( \sum_{i=1}^{p} \frac{C_{p}}{C_{ph}} \right) \right] + \sum_{i=1}^{3} Ki
\]

where:

- \(Dg\) – the total indicator of the degree of danger;
- \(k1, k2, k3\) – weighting coefficients determined in accordance with table 1;
- \(n\) - elements of hazard class 1; \(m\) - elements of hazard class 2; \(p\) - elements of hazard class 3;
- \(c\) - concentration of elements at the testing point;
- \(SF\) is the background concentration.

Table 1 – Anthropogenic pollutant weights

| Hazard class | Weighting factor | Chemical element |
|--------------|-----------------|-----------------|
| 1            | 1               | cadmium, fluoride, lead, zinc |
| 2            | 0.5             | cobalt, copper, molybdenum, Nickel, chromium |
| 3            | 0.25            | strontium, vanadium |

To study the parameters of the natural frame, the degree of anthropogenic load on the territory, as well as the long-term dynamic characteristics of these parameters, Earth remote sensing data obtained from the space satellites Landsat-7 and Landsat-8 were used. To study these parameters, we created an archive of satellite images obtained from the Landsat-8 satellite, covering most cities of Central Russia. The shooting date is 2015-2018 [6].

To study the dynamic characteristics of the natural frame and the degree of anthropogenic load on the territory, the archive was supplemented with satellite images of the same territory taken from the Landsat-7 satellite from 1999 to 2002 [6].
The spatial zoning of the Voronezh city according to the degree of anthropogenic load with the allocation of natural frame zones was carried out based on the determination of the NDVI index, the calculation method of which is based on a comparison of channels in the red and infrared spectrum.

Based on the NDVI index calculated in the ArcGIS software package, we can determine any territory’s category.

The territory of the Voronezh city, as well as suburban 10-kilometer zone, we divided into 4 categories.

1. Territories with a strong anthropogenic load - multi-storey residential buildings, industrial zone, etc.
2. Territories with low anthropogenic pressure - the private sector, low-rise buildings, agricultural land.
3. Water objects
4. Natural frame - green spaces.

3. Results and Discussion

The results of long-term studies of environmental parameters and social conditions in the territory of the city of Voronezh are collected in the medical and environmental atlas of the city of Voronezh, conducted by researchers of the Voronezh State University under the direction of Professor Semyon Kurolap. The atlas contains maps showing the state of the environment, public health, and environmental risks in various parts of the city of Voronezh.

The maps of the atlas show that the main areas of increased pollution are concentrated along the city’s roads. As for dust, construction works make a significant contribution to air pollution.

A cartographic analysis of the complex atmospheric pollution of the city of Voronezh, taking into account all the studied pollutants, allows us to establish the following parameters (fig.1).

In the winter season, the main focus of aerogenic pollution is formed on the low left bank near the fuel and industrial enterprises, as well as along the city’s roads.

In the summer season, two "islands of heat" and increased pollution are distinctly formed on the left and right banks of the Voronezh reservoir, confined to two industrial transport zones.

The main source of environmental pollution in the city of Voronezh is road noise (about 80% of the total background noise in the city). This is due to the presence of intense traffic flows on almost all large and medium-sized highways.

Soil pollution is an indicator of long-term environmental pollution, as many pollutants persist here for many years. The main sources of chemical soil pollution in the city are industrial enterprises, motor vehicles, network engineering, utilities and energy, numerous wastes from construction and finishing works, as well as wastes from consumption.

Among the approaches to assessing the ecological state of the urban environment, one of the most accessible and promising directions is bio-indication of pollution, based on the study of various biological, physiological, anatomical and other deviations in the development of organisms that arise under the influence of external factors. One of the simplest and most affordable methods for such an assessment is to determine the magnitude of fluctuating asymmetry.

Analysis of microclimatic conditions in the city of Voronezh allowed us to identify 6 zones. When determining them, the aeration potential of the atmosphere and the ability of the territory to naturally cleanse itself from anthropogenic pollutants, as well as the integral values of atmospheric pollution, were taken into account.
An integrated medical and environmental assessment of the territory of the city of Voronezh was carried out on the basis of a generalization of regularity statistical connections in the system "environment - public health" using modern environmental, geochemical, probabilistic and geographic information research methods. A feature of our methodology, which has been phased-tested in the conditions of the city of Voronezh, is that various indicators of the state of individual depositing environments and living organisms are used to assess public health risk.

An analysis of spatial zoning according to the data of remote sensing of the Earth in the territory of the city of Voronezh and the suburban ten-kilometer zone showed that most of the studied territory (from 40 to 50%) belongs to the territory with a weak anthropogenic load - agricultural fields adjacent to the city (fig.2-3) [6].
Figure 2. Spatial zoning of the territory of the city district of Voronezh and suburban ten-kilometer zone by NDVI method based on the satellite image LC881760242016240LGN00 of the Landsat-8 satellite dated August 16, 2016 (on the image: Blue - water objects; Green – vegetation (natural frame); Yellow - average anthropogenic load; Red color is a strong anthropogenic load)

The share of the natural frame is 8-10%. The territories that make up the natural frame of the urbanized territory of Voronezh are located mainly on the north side of the city, which significantly reduces their positive impact on the microclimate of the city territory, since the predominant movement of air masses over the territory of the city of Voronezh occurs mainly in the northeast direction [6].

Territories with a strong anthropogenic load are located mainly inside the city [6].

An analysis of the dynamics of changes in the location of various zones over a 15-year period was found to be insignificant reduction of water objects (within the limits of the method error), an increase of 8% of areas with strong anthropogenic load, which may be due to the active construction of residential facilities both in the city of Voronezh and in the suburban zone (fig.2-3). There is also an insignificant increase in the territory related to the natural frame (less than 5%), which may be due to the implementation of various federal and regional environmental programs in this territory [6].
Figure 3. Spatial zoning of the territory of the city district of Voronezh and suburban ten-kilometer zone by NDVI method on the satellite image LE71760242001222KIS00 of the Landsat-7 satellite made on August 10, 2001 (on the image: on the image: Blue - water objects; Green – vegetation (natural frame); Yellow - average anthropogenic load; Red color is a strong anthropogenic load)

4. Conclusion
The main source of environmental pollution and environmental risk factor in the urban district of Voronezh are vehicle emissions (more than 90%).

Analysis of pollution of soil leads to the conclusion that the industrial potential of making a significant contribution to urban pollution.

Analysis of microclimatic conditions in the city of Voronezh allowed us to identify 6 zones. When determining them, the aeration potential of the atmosphere and the ability of the territory to naturally cleanse itself from anthropogenic pollutants, as well as the integral values of atmospheric pollution, were taken into account.

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