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ASSESSMENT OF WIDESPREAD AIR POLLUTION IN THE MEGACITY USING GEOGRAPHIC INFORMATION SYSTEMS

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Approaches for assessing atmospheric conditions in megacities are proposed using an example of St. Petersburg. An article provides results of field observations on atmospheric air quality conducted with a mobile laboratory of Saint-Petersburg Mining University. Temporal distribution was analysed for concentrations of key pollutants: oxides of nitrogen, ammonia, and carbon; sulphur dioxide; hydrogen sulphide; methane; total hydrocarbons. The given framework for interpreting the data on atmospheric monitoring exploits spatial distribution of pollutant concentrations. The proposed ways for solving the problem of atmospheric pollution in certain megacity districts are based on geographic information systems allowing modelling widespread air contamination.

Keywords: atmospheric air, environmental monitoring, geoinformation systems, air pollutants, modelling of widespread pollution

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Introduction. The state of air quality in large megacities and industrial agglomerations is one of the most relevant current environmental issues [2, 8, 10]. Air pollution reaches critical levels in a number of urban areas [7, 9, 12]. Approximately half the populaton of the Russian Federation lives in cities where permissible norms of air pollution in residential areas are surpassed [1, 4, 5].

Averaging the observation results throughout the territory is now a generally accepted approach to assessing the environmental situation in a city. This does not allow separately identifying areas of increased technogenic load that require priority measures and investments aimed at improving the environmental quality.

St. Petersburg takes the third place in air pollution in Russia after Norilsk and Moscow with emissions into the atmosphere amounted to 488 thousand tons per year. High transport load is the main source of air pollution.

Motor transport makes up 85.9 % of the megacity pollutant emissions [3]. According to statistics, 96 % of the population of St. Petersburg lives in conditions of a high degree of atmospheric pollution.

Problem statement. Environmental safety of St. Petersburg population should be ensured by increasing regulatory effectiveness and reducing negative consequences of a technogenic impact on atmospheric air. In this regard, an accurate and rapid assessment of air quality carried out taking into account all climatic, atmochemical and landscape features of the territory of St. Petersburg allows developing a complex of economically viable and environmentally effective actions. It is necessary to involve the mathematical apparatus and GIS technologies to analyse and accurately calculate a level of atmospheric pollution.

Effective control of the atmospheric air cannot be implemented without reliable information on the concentration of a pollutant in any point of space at any time [1, 6, 11, 13]. On the other hand, a real-time physical monitoring is either impossible, or very expensive. In this regard, the purpose of the research is to regulate a negative impact on the atmospheric air in St. Petersburg based on the developed environmental monitoring mechanism and spatially distributed field data using methods of mathematical modelling.

The main tasks of the monitoring studies of atmospheric air in a megacity are:

- determination of sources, factors, and levels of pollution;
- monitoring of already identified sources of pollutant emissions into the atmosphere;
- monitoring of dangerous anthropogenic processes as possible pollution sources;
- assessment of the actual state of atmospheric air;
- air pollution forecast and recommendations on situation improvement;

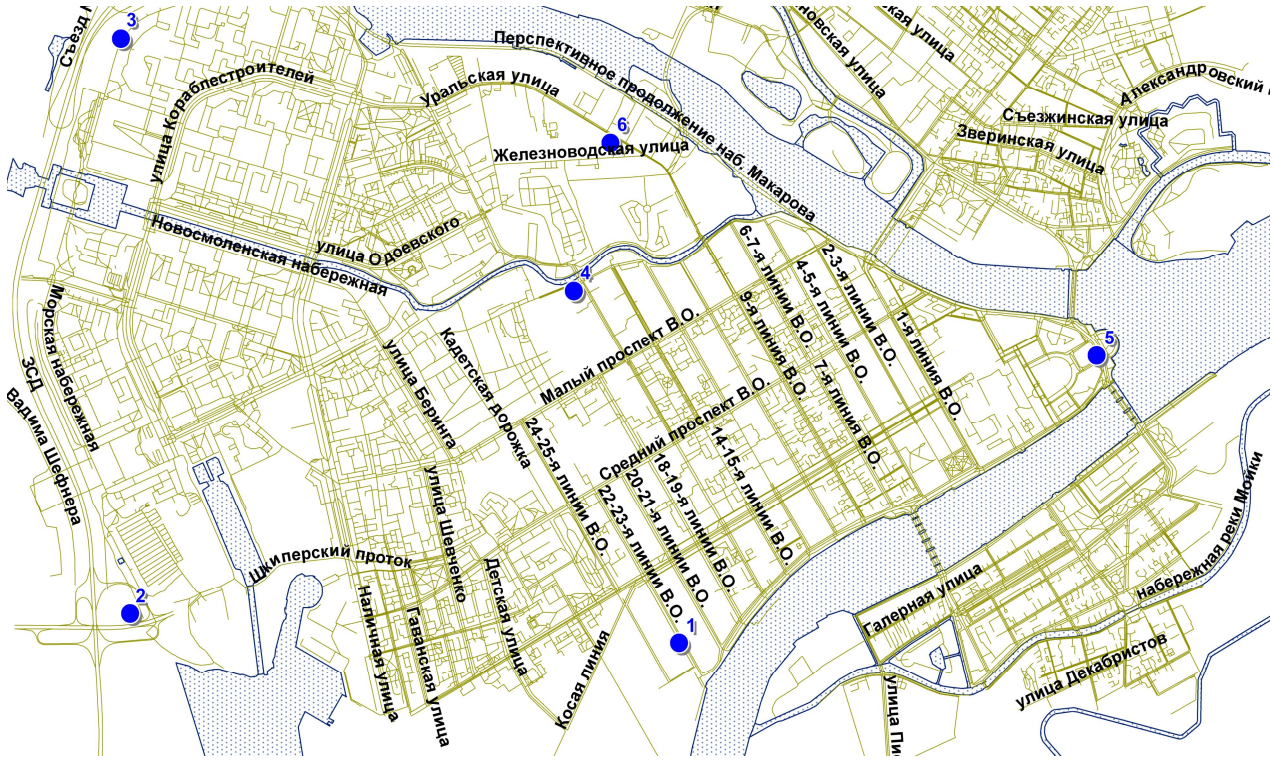


Fig.1. Location of control points

• selection of the main air pollutants taking into account retrospective observations and data on background indicators.

The results of reliable correctly conducted long-term observations, statistical processing of the results, and determination of the main parameters of air pollution allow not only determining the actual state of atmospheric air, but also evaluating the effectiveness of environmental protection measures, correcting the list of priority pollutants, determining a contribution of various sources to total atmospheric pollution, and regulating pollutant emissions.

The territory of Vasilievsky Island was a model research object. The sampling was conducted in six points marked on Fig.1.

Methodology. Mobile observation posts were used to conduct detailed monitoring of atmospheric air on Vasilievsky Island. The mobile posts are needed for a regular sampling of atmospheric air since from the economic point of view this option is the most acceptable for examination of the territory of a megacity in comparison with the installation of a stationary post.

Representativeness of observations (authenticity of the received information) for the state of the air basin is determined by the correct location of a mobile observation post that is installed in places determined by conducting reconnaissance surveys i.e. a preliminary revision of the state of the air environment and a study of meteorological conditions.

The survey of the territory using mobile technical means on a grid with a pitch of 1000 m was carried out for this purpose. Average daily sampling was performed at the grid nodes (4 single samples during the day at regular intervals). The samples were examined for the content of nitrogen oxides (NO_2), ammonia (NH_3), carbon (CO), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), methane (CH_4), and hydrocarbons (C_nH_m) in the air.

The mobile ecological laboratory of the Mining University was used for the air quality research. The mobile laboratory is designed for sampling measurements and data processing by the crew both in the standalone mode and for delivery of samples and data to the place of further stationary processing. The mobile environmental laboratory based on the Mercedes-Benz Vario is equipped with a gas analysing installation, modern gas analysers, a set of air intake devices, an information collection and processing unit, an autonomous power supply, and a life support system.

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The gas analysing installation is intended for installation of gas analysers, sampling device, a meteorological complex, and an information collection and processing system; it provides a stable damping of vibrations during the movement of an ecological post.

Gas analysers operate in automatic mode and allow determining concentrations of the following pollutants in the ambient air: nitric oxide, sulphur dioxide, carbon monoxide, methane and total hydrocarbons, suspended particles with a diameter of 10 μm or less, ammonia, and hydrogen sulphide.

Operation of the gas analysing equipment is controlled by a data collection and management system that provides the solution for the following tasks:

- automatic control of analytical (measuring) equipment;
- obtaining measurement results from gas analysers;
- automatic execution of diagnostic procedures for measuring equipment and self-diagnostic procedures for the system;
- maintenance of databases of measurement results;
- keeping logs (databases) of diagnostic and self-diagnostic results.

Meteorological complex allows measuring the speed and direction of the wind, temperature, pressure, and humidity of the air.

The air intake kit serves for sampling, heating to the required temperature and supplying the specimen to gas analysers and a sampling device.

The number of control points was determined depending on the level of air pollution, homogeneity of emissions, the area of the investigated territory, and local topography.

The detour order of route posts must be the same to obtain reliable data on concentrations of harmful substances, but it was monthly changed so as to perform air sampling at each point at different times of the day.

The averaged results of measurements over a 20-minute period are displayed on the screen of a personal computer in a table form. An example of the obtained air pollution monitoring data at point 1 is presented in the Table.

Example of presentation of measurement results obtained by the mobile laboratory

Measurement time	CO		NO		NO_2		NH_3		SO_2		H_2S	
hours:minutes	mg/m^3	Excess over MPC	mg/m^3	Excess over MPC	mg/m^3	Excess over MPC	mg/m^3	Excess over MPC	mg/m^3	Excess over MPC	mg/m^3	Excess over MPC
12:00	1.193	0.4	0.015	0.2	0.051	1.3	0.020	0.5	0.009	0.2	0.003	0.4
12:20	1.103	0.4	0.024	0.4	0.064	1.6	0.017	0.4	0.012	0.2	0.002	0.3
12:40	0.838	0.3	0.015	0.2	0.040	1.0	0.015	0.4	0.011	0.2	0.002	0.3
13:00	0.588	0.2	0.006	0.1	0.034	0.8	0.015	0.4	0.008	0.2	0.004	0.5
13:20	0.595	0.2	0.009	0.1	0.038	1.0	0.013	0.3	0.006	0.1	0.003	0.3

It should be noted that only NO_2 concentrations exceeded the Maximum Permissible Concentration (MPC) during all the measurements.

An example of a linear distribution of NO_2 concentrations is shown in Fig.2.

The results of the studies were as follows:

- the excess of the MPC during all the measurements was not observed for CO in general and there is a tendency of concentration decrease;
- local concentration maxima were observed in the analysis of SO_2 in the atmospheric air without exceeding the established norms;
- NH_3 concentration in the ambient air decreased over time, an excess of the MPC was not fixed, neither there were local minima or maxima of concentration;
- the H_2S levels were stable and within the limits of the daily average MPC;
- the NO_2 concentrations were repeatedly higher than the MAC during the whole period of observations, with an exceedances range of 1.0-3.7 times.

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Discussion. Control of pollutant contents at the sampling points only does not allow describing the ecological situation in general. In this regard, the areal distribution of pollutant concentrations is of the greatest interest in assessing the state of atmospheric air in megacities.

Geographic Information Systems (GIS) possess currently the most convenient and powerful resources to display information on levels of the widespread air pollution directly on the electronic map of a megacity. Modelling of pollutant spreading processes in the air with the application of capabilities of geoinformation technologies is a methodical tool allowing to estimate anthropogenic load, both visually and quantitatively.

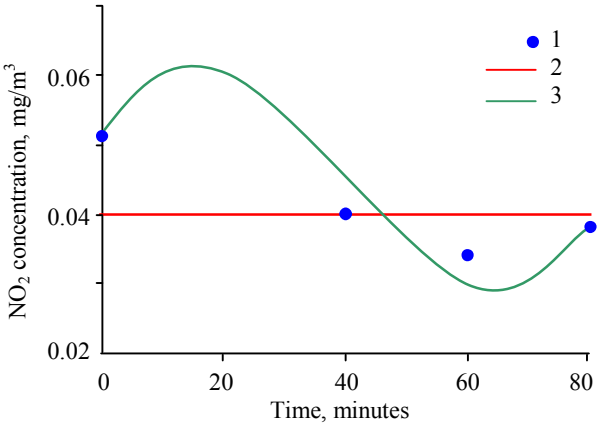


Fig.2. Linear distribution of NO_2 concentration
Conventional signs: 1 – empirical data;
2 – third-order polynomial; 3 – daily average MPC

The MapInfo Professional geoinformation system was chosen to solve the task. This software is one of the world leaders in the field of spatial data representation and processing. In addition to the standard functions of database management systems, MapInfo Professional allows to collect, store, display, edit, and process the map information stored in the database, taking into account the spatial positions of objects representing, for example, the topography and the terrain situation.

A thematic mapping is used for cartographic analysis of spatial data in MapInfo GIS. This set of tools allows creating ranges of values, columnar and circular diagrams, graded symbols, the density of points, individual values, and continuous surface.

Triangulated Irregular Network (TIN) and Inverse Distance Weighting (IDW) interpolation methods are most applicable in MapInfo GIS for interpreting monitoring information.

When using the IDW interpolation method, the points are weighed in such a way that influence of the known value of the point declines with increasing distance to an unknown point, the value of

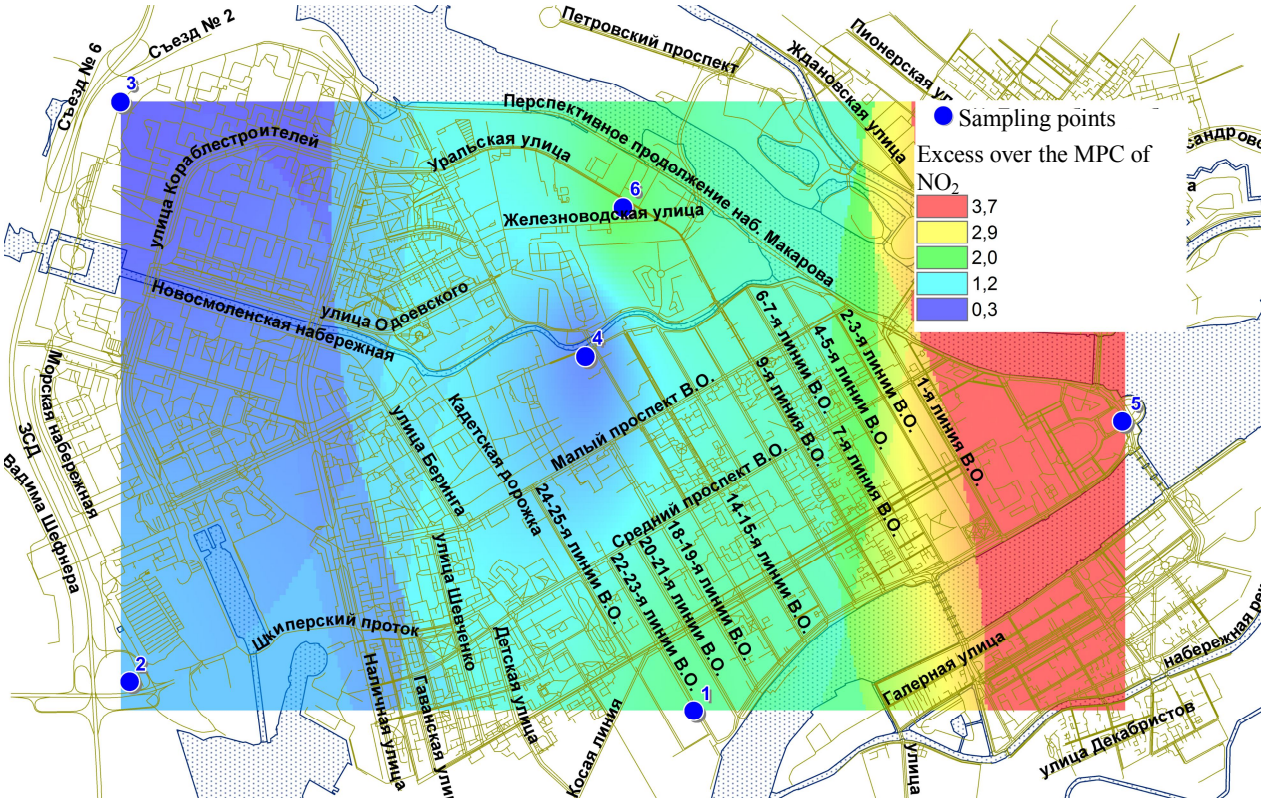


Fig.3. Resulting map of NO_2 areal distribution in the atmospheric air

which must be determined. The common TIN algorithm creates a surface consisting of triangles formed by the nearest points. For this purpose, circles are drawn around the data collection points and their intersections are connected to a network of compact triangles adjacent to each other without intersections and discontinuities.

IDW interpolation method proved to be more acceptable when constructing the resulting thematic maps.

An example of the final map is shown in Fig.3, where the change in NO_2 content in the atmospheric air is shown as an enrichment factor calculated in relation to the Maximum Permissible Concentration of the gas.

Conclusion. Analysis of the gained results suggests ways of solving the problem of atmospheric air pollution in specific metropolitan areas where the exceedances of environmental standards are found. Such measures include:

• carrying out works to optimise the traffic organisation in megacities, improvement of road construction;

• equipment of megacities with public transport, corresponding to the norms of the Euro-3 ecological standard, i.e. with the use of fuel with improved environmental characteristics;

• improvement of the system of state control over the protection of atmospheric air.

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