Geoinformation technologies in assessment of ecological conditions of industrial territories in the left-bank region of Novosibirsk

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Modern computer technologies, when applied to assessment of environmental pollution, make possible most comprehensive and versatile analysis of atmospheric emissions of harmful substances in a city, estimation of the effect of atmospheric pollution on the human health, and visualization of the obtained results. One of the possible approaches based on the use of MapInfo GIS is presented in this paper.

Introduction

The city of Novosibirsk is characterized by high pollution of the urban atmosphere. This pollution is mostly formed by emissions from heat-and-power plants, boiler houses, and motor transport, which are sources of more than 3 / 4 of pollutant emissions in the city.[4] The level of atmospheric pollution in Novosibirsk is usually classified as very high, and the city itself falls in the list of most polluted Russian cities, although not in the top ten. More than 150 different pollutants are emitted into the urban atmosphere, and the concentration of more than 30 substances exceeds the permissible contamination standards.

In large industrial centers, the environmental pollution has a complex, sometimes mosaic, character even for an individual pollutant. This is explained, first, by wide variety of sources with different emission rate and, second, by complex pattern of pollutant spread caused by the geometry of buildings, nonuniform orography and meteorological conditions in different city districts. Taking into account that the monitored pollutants number in the tens, it is clear that to assess their combined effect on the human health is a very complicated problem from both purely scientific and practical points of view. At the same time, monitoring services have accumulated voluminous information, which is usually presented as reference books and atlases, and sanitary and epidemiological services have the data characterizing the morbidity level in different city districts.[1] These data show that children are most sensitive to the anthropogenic load. The level of the children morbidity in different districts differs markedly, and this fact is attributed to the different level of contamination by totality of pollutants. To estimate the combined effect of the technogenic load, some empiric approaches were proposed.[2,3,5] Implementation of these approaches based on the modern computer technologies allows one to carry out a comprehensive and versatile analysis with visualization of the obtained results. One of the possible approaches based on the use of the MapInfo GIS is presented in this paper.

Estimation of pollution indices

To assess the effect of atmospheric pollution on the human health in different districts, the coefficient of atmospheric pollution was used

$$K_{\text{atm}} = \sum_{i=1}^{n} \frac{c_i}{N\ \text{MPC}_i}, \qquad (1)$$

where “$_i$ is the actual concentration of the ith substance; MPC is the maximum permissible concentration of the ith substance; N is the safety factor equal to 2.3 for substances of the first class of hazard, 1.3 for substances of the second class of hazard, 1.0 for the third class, and 0.87 for the fourth class; n is the total number of pollutants, for which the consequences are assessed.[3]

The degree of atmospheric pollution from different sources is estimated by the combined index of pollution of the urban atmosphere $ the atmospheric pollution index (API):

$$\text{API} = \sum_{i}^{n} \left(\frac{q_i}{\text{MPC}_{is}} \right)^{a_i}, \qquad (2)$$

where q_i is the concentration of the ith substance, in mg / m^3; MPC$_{is}$ is the maximum permissible single concentration, in mg / m^3; a_i is a dimensionless constant that allows one to relate the insalubrity of the ith substance to the insalubrity of substances of the third class of hazard. The constant = for substances of the first, second, third, and fourth classes of hazard is equal to 1.7, 1.3, 1.0, and 0.9, respectively; n is the number of pollutants included in the calculation.[5]

Initial data

To assess the degree of atmospheric contamination by different sources, we used the data of the municipal ecology committee on the emissions of pollutants, in particular, formaldehyde, carbon monoxide, nitrogen dioxide, soot, and solid particles. In addition, we used the fields of the combined atmospheric pollution index calculated in the West-Siberian Regional Computing Center (Zap.-Sib. RVTs) for 22 substances emitted by 176 Novosibirsk enterprises (Fig. 1). The list of pollutants included dust, nitrogen dioxide, sulfur dioxide, phenol, ammonia, carbon monoxide, hydrogen fluoride, xylol, acetone, white spirit, toluol, chlorine, sulfuric acid, nitric acid, ethyl acetate, phthalic anhydride, trichlorethylene, butyl acetate, methyl alcohol, ethyl alcohol, and benzine. The atmospheric pollution index was calculated using the grid with a step of 1000 m, which covered the city territory. This allowed the city area to be considered in sufficient detail, what is an obvious advantage when compiling ecological maps. The information about the human health was given by the municipal sanitary and epidemiological service.

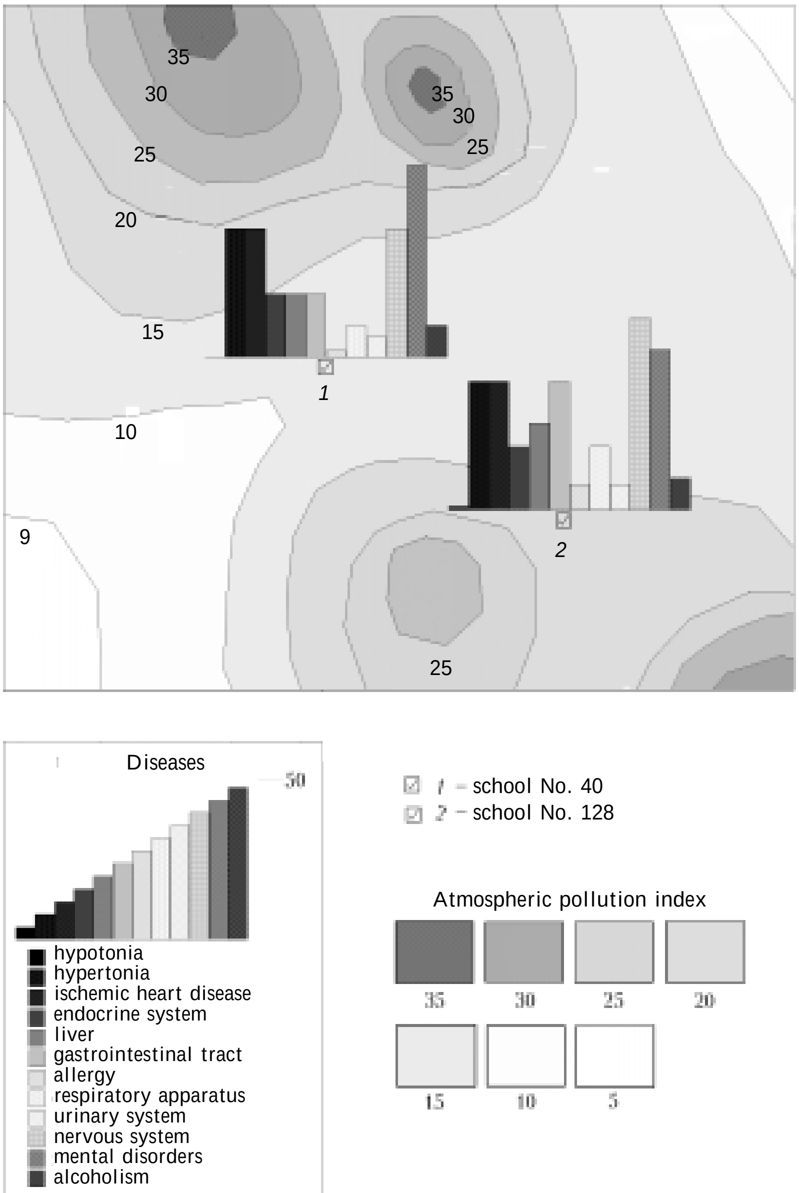

Fig. 1. Atmospheric pollution index. Children morbidity.

Results of data representation and analysis

Geoinformation technologies are an efficient tool for representation and analysis of dissimilar data. Experiments were conducted for the Leninsky and Kirovsky Districts of the city of Novosibirsk taken as an example with the use of the MapInfo GIS and the data of the municipal ecology committee, West-Siberian Regional Computing Center, and sanitary and epidemiological service. At the first stage, the digital map of these districts was compiled. The map included such basic elements as hydrography, flora, blocks of buildings, industrial enterprises, schools, etc. (Fig. 2).

Then we compiled the tables characterizing the degree of the pollution effect on the human health.

The next and most important stage was joint analysis of the data and selection of the proper visualization tools. Thus, the information on pollution sources is represented most comprehensively and compactly as circle diagrams, which clearly demonstrate the ratio of the groups of pollutants corresponding to different classes of hazard (Fig. 3).

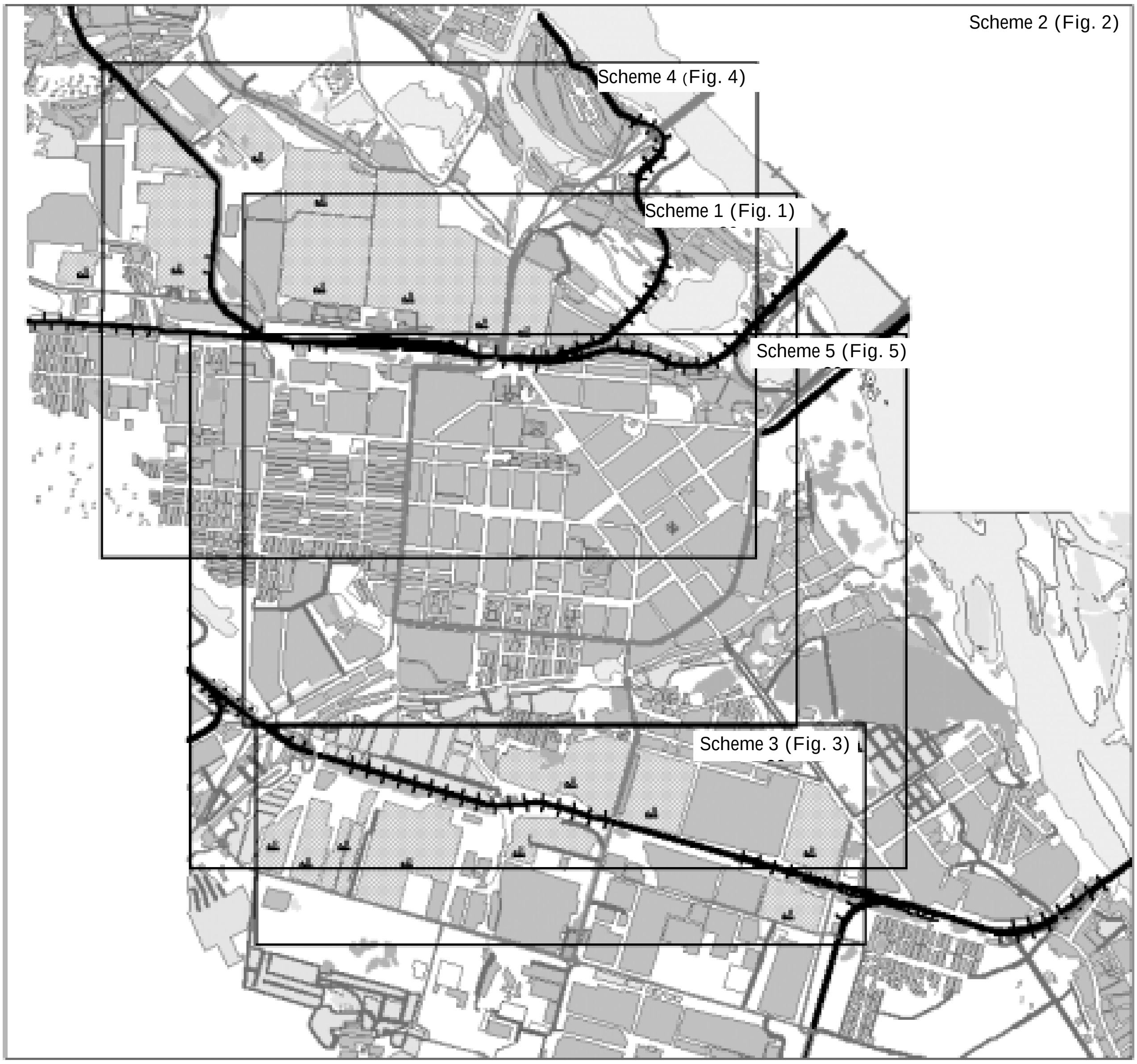

Fig. 2. Map of the Leninsky and Kirovsky Districts of Novosibirsk.
□ $ Location of schemes on the district map.

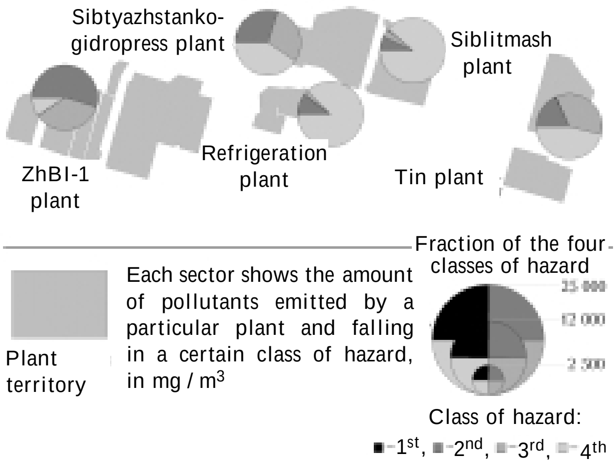

Fig. 3. Fractions of pollutants falling in different classes of hazard emitted by plants in the Leninsky and Kirovsky Districts of Novosibirsk.

Representation of information in the form of lines with the same concentration of pollutants (isolines) shows their distribution over the district territory. Figure 4 demonstrates the contamination of the urban atmosphere by carbon monoxide and solid particles.

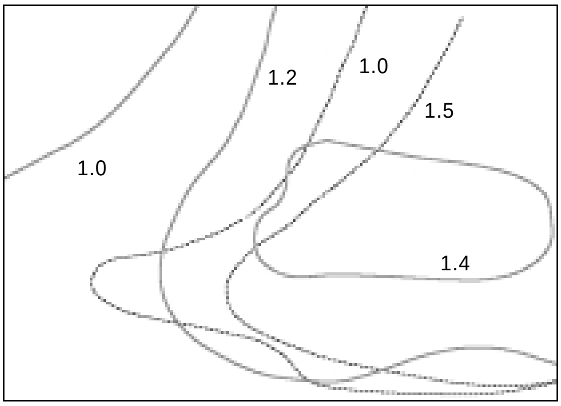

Fig. 4. Atmospheric contents of carbon monoxide (dotted curves) and solid substances (solid curves), in mg / m^3.

Using the calculated values of K_{atm} [Eq. (1)], we drew the grids (pollution areas with conditionally homogeneous amount of pollutants), which represent the degree of contamination of the urban atmosphere by soot and carbon monoxide (Fig. 5). It is seen from Fig. 5 that even for two substances from different classes of hazard the pattern of the spatial distribution and, correspondingly, the risk to the human health becomes more mosaic. If for individual substances (see Fig. 4) the centers of maximal pollution are clearly seen, then the values of the atmospheric pollution index are distributed rather inhomogeneously over the territory under analysis. The risk parameter is more complex as well. Thus, the level of carbon monoxide varies 1.5 times, while the level of pollution with solid particles varies 1.75 times, and K_{atm} varies 2.25 times.

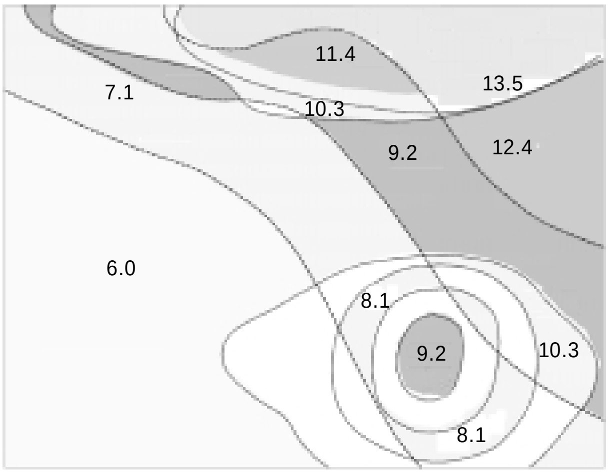

Fig. 5. Combined atmospheric pollution index calculated for soot and carbon monoxide (in mg / m^3); isolines of soot concentration (- - -); isolines of carbon monoxide concentration (┅┅); light fields corresponds to the areas that cannot be classified in this way because of higher detailing and impossibility to be represented on the black-and-white scale.

The atmospheric pollution index (API) calculated by Eq. (2) can be used for combined assessment of the risk. The map layer representing the combined atmospheric pollution index is shown in Fig. 1. The city territory was divided into parts according to the following categories of hazard:

$ territories of the first category of hazard with API > 30;

$ territories of the second category of hazard with 30 > API > 20;

$ territories of the third category of hazard with 20 > API > 10;

$ territories of the fourth category of hazard with API < 10.

For illustration, the pollution grids are divided into subgrids with a step equal to five. As is seen from Fig. 1, almost all the left-bank territory of the city has the API larger than 10.

To reveal the effect of the technogenic load on the human health in industrial centers, examination of schoolchildren on the left-bank territory of Novosibirsk was performed. Based on these data, we drew column diagrams showing the number of children with ischemic heart disease, hypertonia, diseases of respiratory tract and urino-genital system, cholelithiasis, kidney diseases, etc. (see Fig. 1).

A total of 24 layers were drawn, namely, the diagram of emissions of pollutants of the first class of hazard (vanadium pentoxide, cadmium monoxide, lead and its inorganic compounds, lead monoxide, lead acetate, hexavalent chrome) from different plants; the first diagram of emissions of pollutants of the second class of hazard (hydrogen sulfide, carbon bisulfide, fluoride compounds, phenol, calcium fluoride, sodium hexafluoroaluminate, nitric acid, formaldehyde, chlorine, zinc sulfate, carbon tetrachloride, coal ash);

the second diagram of emissions of pollutants of the second class of hazard (aluminum fluoride, nitrogen dioxide, hydrogen fluoride, hydrogen chloride, sulfuric acid, hydrochloric acid, silicon tetrafluoride, manganese and its compounds, copper oxide, arsenic, arsenious anhydride); the first diagram of emissions of pollutants falling in the third class of hazard (nitrogen dioxide, suspended matter, sulfurous anhydride, sulfur dioxide, ferric oxide, inorganic dust with 70% content of harmful substances, with 20 to 70% content of harmful substances, and with 20% content of harmful substances, soot, *n*-butyl alcohol); the second diagram of emissions of pollutants falling in the third class of hazard (toluol, zinc oxide, chamotte, dinas, xylol dolomite, acetic acid, magnesium oxide, zinc nitrate, zinc oxide, acetaldehyde, grain dust, cotton dust); the diagram of emissions of pollutants falling in the fourth class of hazard (benzine, butylacetate, hexane, ethyl alcohol, carbon monoxide, saturated hydrocarbon, ethylacetate, acetone, ammonium, butane); circular diagrams demonstrating the total amount of pollutants falling in different classes; isolines of soot content in the atmosphere; isolines of nitrogen dioxide content in the atmosphere; isolines of carbon monoxide content in the atmosphere; isolines of formaldehyde concentration in the atmosphere; isolines of the concentration of solid particles in the atmosphere; isolines of dust concentration in the atmosphere; places of emergency emissions of harmful substances; potential places of emergency emissions or discharges of harmful substances; grids of the dust load on the atmosphere; grids of K_{atm} calculated for soot and carbon monoxide; grids of K_{atm} calculated for soot, carbon monoxide, and nitrogen dioxide; grids of K_{atm} calculated for soot, carbon monoxide, nitrogen dioxide, and solid particles; grids of the atmospheric pollution index; children morbidity in some urban schools; statistics of oncological diseases; statistics of mortality; places of sewage discharge.

These layers include the information on the amount of pollutant emissions for every source and K_{atm} and API calculated by the above equations.

Conclusions

The use of modern computer technologies provides for the comprehensive analysis of ecological data with visualization of the obtained results. One of such approaches based on the MapInfo GIS is presented in this paper.

The obtained results demonstrate the principal possibility of using GIS to assess the ecological state of a territory and the efficiency of the GIS use for real-time prognosis.

Acknowledgments

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References

1. *Atlas of Chemical and Radioactive Pollution of Atmospheric Air, Surface Water, Soil, Snow Cover, and Atmospheric Precipitation for 1980$1992* (Zap.-Sib. RVTs, Novosibirsk, 1993), 107 pp.
2. N.A. Aganzhanyan, Yu.P. Gichev, and V.I. Torshin, *Human Ecology* (Novosibirsk, 1997), 350 pp.
3. Yu.P. Gichev, *Current Problems of Ecological Medicine* (SB RAMS, Novosibirsk, 1999), 183 pp.
4. *Normative Documents of Municipal Ecology Committee œ2TR $ AirB* (1999), 32 pp.
5. E.Yu. Bezuglaya, *Monitoring of the Atmospheric Pollution in Cities* (Gidrometeoizdat, Leningrad, 1986), 120 pp.