The Assessment of the Pollution of the Atmosphere's Surface Layer with Use of GIS-Technologies

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Abstract[1]

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The article gives the estimation of city's surface layer of the atmosphere contamination, caused by emission point source, using Geographic Information System methods.

1. Introduction

The problem of the quality of ambient air is particularly acute in the resort cities of the subtropical zone of Russia. On the one hand these resorts are large cities with ports that are lead to large technogenic load in the air basin. And on the other hand they are a resort and tourist center, that's why the highest demands are made to air quality. Misallocation, inexpedient economic and municipal activities, use of fossil fuels, high recreational stress during the season leads to a big pollution on resort resources. Air pollution is a real threat to the recreational potential of resorts and may be harmful to human health [1].

Specificity of subtropical region of Russia is the average high temperature and humidity, lack of mountain-valley circulation of air, dead zones, and even smog. All this factors make technogenic processes in the atmosphere more complexly and increase their negative impact. This requires the development of research in this direction and refinement of existing computational methods [2].

The main sources of air pollution at the resort are transport and thermal power plant. One of the main tasks is finding alternative ways to develop the resort, based on using of new technologies in these industries. First of all, an adequate analysis of the ecological state and its presentation in the optimal form for decision making is required.

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2. The aim, object and methods of research

The aim of the study is to assess the contamination of the atmosphere surface layer of a resort area by the emissions from major sources of pollution – boiler-houses. The object of research is a network of thermal power plant (boiler and thermal power plants) of the resort city Sochi. The estimation was made in the main administrative districts of Sochi territorial recreational complex: Adlersky, Lazarevsky, Central and Khostinsky.

Data for calculation were provided by Dr. Sadilov, Department of Environmental Engineering from Sochi State University for Tourism and Recreation (SUTR) [2].

The common regulatory model and «The methodology of calculating the concentrations of pollutants in the atmosphere from emissions of enterprises (AURD-86)» [3] were used to calculate the distribution of contaminants. In addition, we used geographic information technologies (GIS) as one of the modern tools for researcher in the field of assessment of human impact on the environment of the resort area.

The main advantage of GIS is the ability to determine the position of an object in space and associate with his location all the information that it describes (including – environmental issues).

GIS-technologies have a wide range of tools that allow users to search, analyze and edit digital maps and provide them additional information about the objects.

Mane stages of this research are:

1. Implementation of the methodology of calculating the concentrations of pollutants in the atmosphere from emissions of enterprises (AURD-86) in the form of a software module based on GIS.
2. Conducting the calculation of surface concentrations of various pollutants from the existing point sources (boiler-houses of Sochi).

3. Build distribution maps of the pollutants surface concentrations in the territory of the city by results of the calculation in a GIS environment.
4. Development of the control module which enable the user to modify input parameters and executing various experiments.

Module for calculating the surface concentration of harmful substances with ejection of gas-air mixture from a single point source with a circular mouth (for boiler-houses) was developed. It is based on software ArcGIS 9.3 (ESRI) on VBA programming language.

3. Implementation of methodology based on GIS

3.1. Methodology of calculating the concentration of pollutants

The maximum surface concentrations of pollutants C_m (mg/m^3) is defined by (1) from the methodology AURD-86 [3]:

$$C_m = \frac{A * M * F * m * n * \eta}{H^2 \sqrt[3]{V_1 \Delta T}}, \quad (1)$$

where A – dimensionless coefficient depending on the temperature stratification of the atmosphere;

M (g/sec) – the mass of pollutant emitted into the atmosphere per unit of time;

F – dimensionless coefficient that takes into account the sedimentation rate of harmful substances in the air;

m and n – dimensionless coefficients taking into account the conditions of exit gas mixture from the mouth of the emission source;

H (m) – the height of emission source above ground level (for land-based sources in the calculations adopted $H = 2$m);

η – dimensionless coefficient that takes into account the influence of terrain; η = 1 for terrain with elevation changes not exceeding 50 m to 1 km,

ΔT (°C) – the difference between the temperature of exhaust gas mixture T_g and the temperature of the ambient air T_v;

V_1 (m^3/sec) – consumption of gas-air mixture, determined by (2)

$$V_1 = \frac{\pi D^2}{4} \omega_0 , \quad (2)$$

where D (m) – diameter of the mouth of the emission source;

ω_0 (m/sec) is the average velocity of gas-air mixture exit from the mouth of the emission source.

Surface concentration reaches a maximum value under adverse weather conditions at a distance X_m (m) (3) from the source.

$$X_m = \frac{5 - F}{4} d H \quad (3)$$

where d – dimensionless coefficient depending on parameters f, v_m, v'_m и f_e.(4, 5, 6, 7):

$$f = 1000 \frac{\omega_0^2 D}{H^2 \Delta T} \quad (4)$$

$$v_m = 0{,}65 \sqrt[3]{\frac{V_1 \Delta T}{H}} \quad (5)$$

$$v'_m = 1{,}3 \frac{\omega_0 D}{H} \quad (6)$$

$$f_e = 800 (v'_m)^3 \quad (7)$$

F, H from (1).

3.2. The GIS application for calculating the fields of pollution

There are 3 types of calculation in module:

- For all boiler-houses of city.
- For all boiler-houses from one of the four regions.
- For a boiler-house, located to the appropriate address.

In addition, two possibilities are realized:

- User input of the pollutants mass M (g/sec).
- The calculation of the pollutants mass M (g/sec) by the method of rapid assessment of pollutants emissions by (8) from [4]:

$$M = \sum_{i=1}^{m} g_i * P_i * 10^6 \quad (8)$$

where g_i (g/kg, kg/t, kg/1000m^3) – specific pollution emissions of i-th boiler (tabular data);

P_i (kg/yr, m^3/year) – a fuel consumption in the i-th boiler per the year.

Input datasets and possibilities of the experiment depend on the method of calculating.

Data from the attribute table of the layer «Boiler-houses» is used when calculated for the region.

The user may change the following parameters:

- Temperature of exhaust gas-air mixture T_g;

- Coefficient depending on the temperature stratification A;
- Dimensionless coefficient that takes into account the influence of terrain η;
- Dimensionless coefficient that take into account the rate of subsidence of harmful substances in the air F;
- Maximum permissible concentrations (MPC) of pollutants;
- Select M define method: by input known masses of pollutants or by the method of rapid assessment of pollutants emissions.

When calculating the emissions from a single boiler-house address of boiler-house is selected from the list. The number of source pipes, its height, the diameter of the source mouth, a flow rate of gas-air mixture and fuel consumption in the i-th boiler for the year (as recalculated in consumption per second), the number of boilers, as well as a fuel, is taken from the attribute table layer «Boiler-houses».

The other parameters are given in the form of a «default», but all parameters can be changed in the form of calculation. This gives opportunity to execute different experiments: for example, change of fuel type, geometric characteristics of the source or the emission rate of pollutants affects the value of surface concentration.

Graph of the distribution of values of the concentration of pollutants at a distance from the source is displayed when calculating for a single boiler-house. It can be saved or exported (Fig. 1).

It should be noted that, if the user does not put the wind speed, the calculation is performed for the initial parameters of the tube with dangerous wind speed according to the method AURD-86. If a given wind speed u is different from the dangerous wind velocity u_m, then the coefficients of r and p are calculated by formula (4) - (8) of [1], depending on the ratio u/u_m.

$$r = 0{,}67(u/u_m) + 1{,}67(u/u_m)^2 - 1{,}34(u/u_m)^3,\ u/u_m \le 1 \quad (4)$$

$$r = \frac{3(u/u_m)}{2(u/u_m)^2 - (u/u_m) + 2},\ u/u_m > 1 \quad (5)$$

$$p = 3,\ u/u_m \le 0{,}25 \quad (6)$$

$$p = 8{,}43(1 - u/u_m)^3 + 1,\ 0{,}25 < u/u_m \le 1 \quad (7)$$

$$p = 0{,}32u/u_m + 0{,}68,\ u/u_m > 1 \quad (8)$$

They are entered to the formulas for calculating C_m (9) and X_m (10):

$$C_{mu} = r * C_m \quad (9)$$

$$X_{mu} = p * X_m \quad (10)$$

In addition, it is important to select the wind direction on the rumba or the calculation is carried out to determine the maximum spread of pollutants in any direction of the wind. In second case, plume's axis shifted sequentially at 1° clockwise, forming the contours of the same concentrations (see the example of constructing the field concentrations in the atmospheric surface layer for a single point source with a circular brute wind direction in [5]).

The calculation will show a plume directed into a selected direction (Fig. 2a) or a maximum concentration field of pollutants (Fig. 2b).

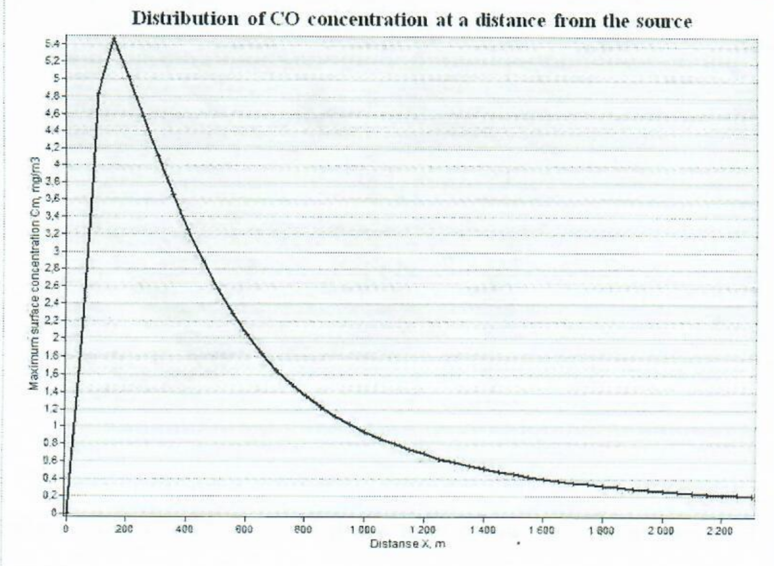
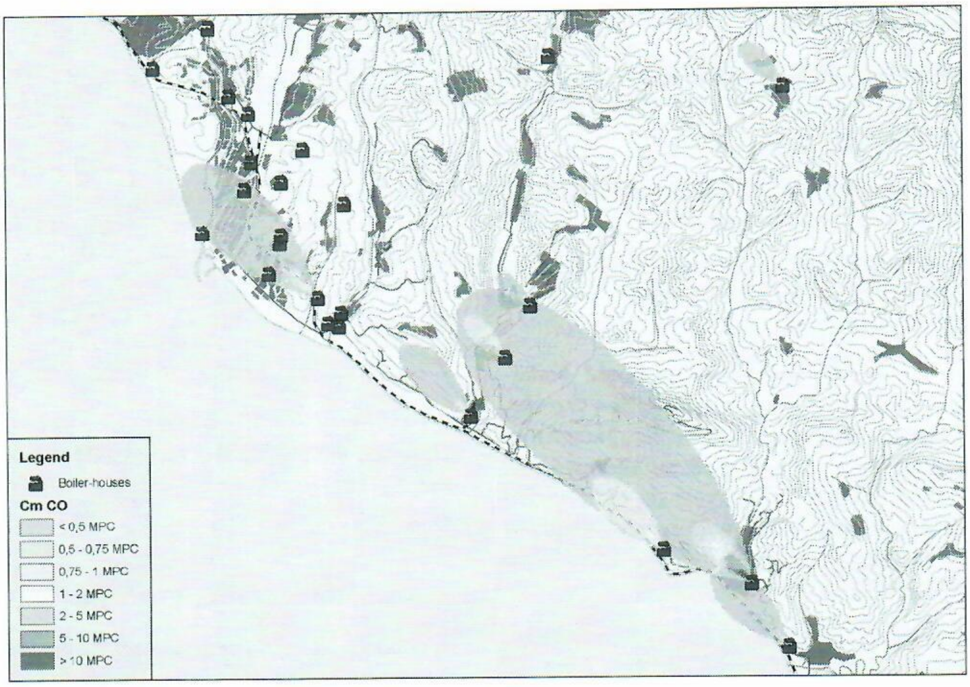
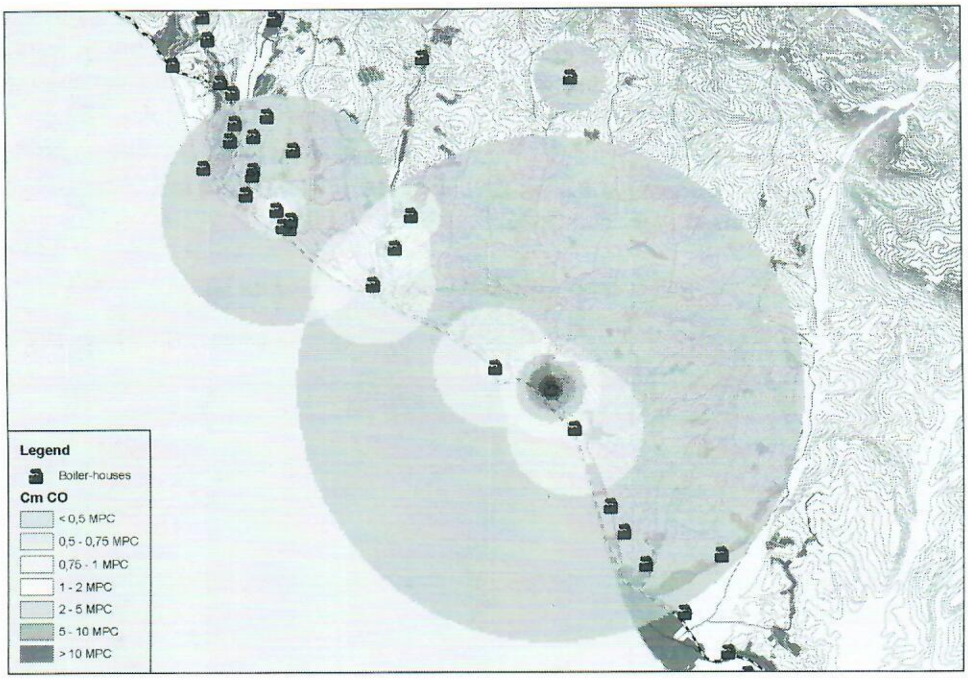


Fig. 1. Distribution of CO concentration at a distance from the source (m)



a



b

Fig. 3. Cm by boiler-houses: *a* – north-west wind; *b* – with circular enumeration of winds

4. Conclusion

- It should be noted that almost all currently available software packages are based on the method of calculation described in AURD-86.
- All other systems can be used only in informational and research purposes because they haven't necessary certification.
- One of the results obtained in this study was the use of GIS techniques – applying technologies for visualizing the results of emission sources inventory and the preparation of the calculation results in a set of thematic maps.
- The developed module provides easy to use interface and allows the researcher to make the calculation based on available data and set their own conditions of the experiment (not only the existing meteorological parameters, but also the basic parameters that characterize the use of new technologies).

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