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MODELING OF THE POLLUTANTS SPREAD IN AMBIENT AIR USING GIS TECHNOLOGY ACCORDING TO OND-86 TECHNIQUE

The paper analyzes main problems of modeling by OND-86 technique using GIS. Mathematical model of transformation of the coordinates system used in the technique, to geographical coordinates of the area is elaborated. Programming tool of GIS intended for modeling of pollutants spread in the air is developed.

Key words: modeling, GCD-86 technique, GIS, mathematical model, coordinate system, pollutants, atmospheric air.

Growing application of GIS technologies in environmental monitoring is due to the opportunity to conduct spatial analysis of data using a powerful tool, which is the integral part of most modern GIS [1]. Existing software tools (for example, "Aeolus 2000» <http://www.sfund.kiev.ua/rus/products/ecology.htm>, «ROSA-Air» <http://www.ecolida.ru/vozduh.html> or UPRZA "ECOCLOGY» <http://www.atmosfera-npk.ru/page6.htm>, etc.) developed for calculation of ground-level concentrations of pollutants without usage of GIS in most cases are limited by graphic image of the plan area with limited possibilities of spatial analysis. At the same time, the use of GIS for modeling of pollutants spread is reduced to a small number of mathematical techniques of modeling and data processing, adapted for usage in GIS [1, 2]. Thus, only valid in Ukraine and the CIS countries method of pollutants propagation modeling' OND-86 "[3] for use in GIS requires improvements, namely, coordinate systems change for calculation of concentration fields from emissions of a group of sources.

The aim of this research is the adaptation of the existing technique (OND-86) for application in GIS. The research comprises the solution of the following problems: development of mathematical model of transformation of the coordinate system used in GCD-86 technique, into geographical coordinates of the region to be investigated; develop GIS software toolkit for modeling the spread of pollutants in the air.

Mathematical model. For the calculation of ground-level concentrations of pollutants Cartesian coordinate system is used, where the beginning of the coordinates coincides with the sources of emission coordinates. And since the tail of one source of emissions (ES) may coincide with the tail of another source, then there appears the task of creating a mathematical model required for transformation from coordinate system of OND-86 [3] technique to geographic coordinates of GIS for calculation of grid points in the geographic coordinates system.

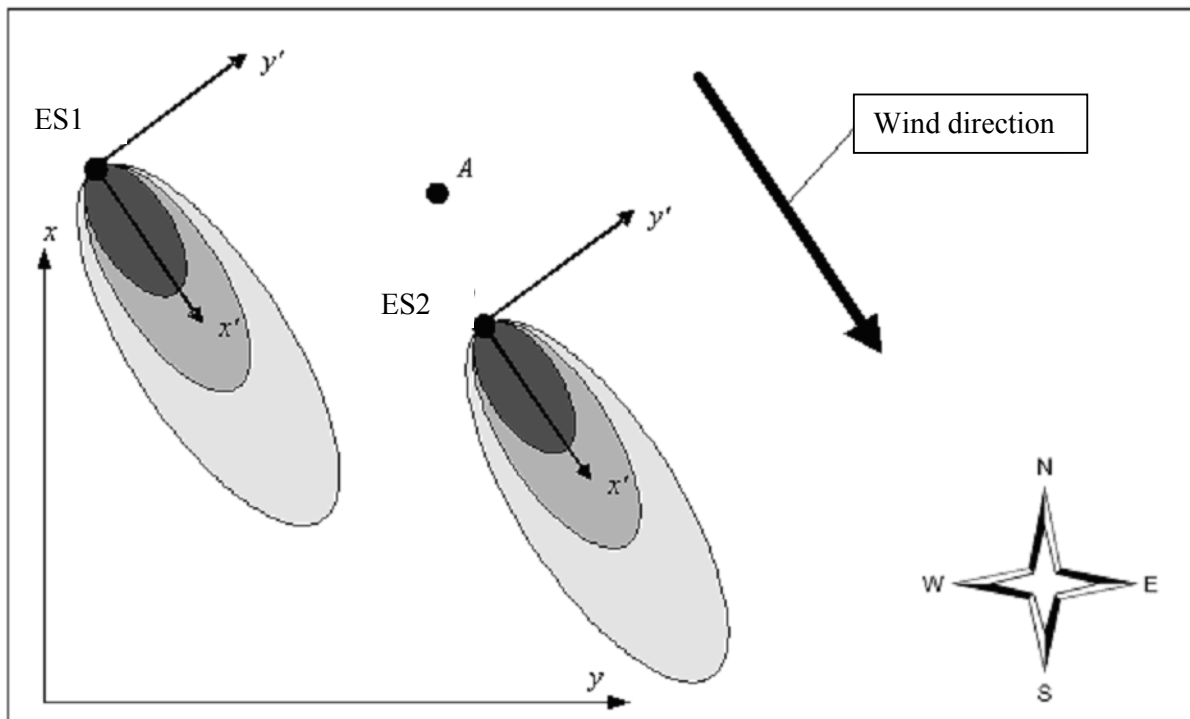
The calculation of ground-level concentrations of pollutant emissions from stationary sources is carried out in the direction of the wind, and concentrations values can be determined only at values of $x' > 0$. Thus, the reduction of technique coordinates to geographic coordinates and in the opposite direction requires the account of wind direction, with the exception of those points for the given ES, which do not fall under emission tail (e. g, point A in Fig. 1 does not fall under the action of pollutants from ES2). The combined effect of pollutants emission of each source anywhere in the area is defined by algebraic sum of concentrations, calculated in this point from emission of each source (1) or other relations of the technique [3]:

$$c = \sum_{i=1}^N c_i, \quad (1)$$

where c_i – concentration of pollutants from the emissions of i^{th} ES at this point, N – number of ES.

Fig. 1. Scheme of the region map with coordinate systems according to OND-86 technique (the direction of the axis x' of emission tail coincides with the direction of the wind);

ES1, ES2 – sources of emissions; x' , y' – the axis of the coordinate system according to OND-86 technique



Initial conditions:

1. Total values for pollutants are determined by the expression (1), but the algorithm of total concentration depends on mutual location of ES.

2. Direction of x axis (emission tail) coincides with the direction of the wind.

Common approach to the construction of thematic maps of pollutants scattering from stationary sources emissions is the following:

1. Set coordinates grid to determine the pollutants concentration with a certain step;
2. For each point of the grid determine the coordinates $x'y'$ in the coordinate system (see Fig. 1);
3. For each point of the grid calculate according to technique [3] total concentration by the expression (1).

As the number of ES, in general, can be N , then bring the geographical coordinates to a coordinate system of OND-86 technique will be realized for each of them.

Coordinates of the point at which the calculation of pollutants concentration is performed, in general case, have the coordinates x'_A and y'_A in coordinate system of the technique $(x'y')$ and x_A and y_A in geographical system of coordinates. To perform the calculation the coordinates of ES (x_{ES} and y_{ES}) are also required. Proceeding from these assumptions, in general form the coordinates of a random point of the grid for OND-86 technique will be determined from the relations (2) - (4) (Fig. 2).

$$\beta = \begin{cases} \arctg \frac{y_A - y_{ES}}{x_A - x_{ES}} & \text{if } (x_A > x_{ES}) \cap (y_A > y_{ES}) \\ 180^\circ + \arctg \frac{y_A - y_{ES}}{x_A - x_{ES}} & \text{if } (x_A < x_{ES}) \cap (y_A < y_{ES}) \\ 360^\circ - \arctg \frac{y_A - y_{ES}}{x_A - x_{ES}} & \text{if } (x_A > x_{ES}) \cap (y_A < y_{ES}) \\ 180^\circ - \arctg \frac{y_A - y_{ES}}{x_A - x_{ES}} & \text{if } (x_A < x_{ES}) \cap (y_A > y_{ES}) \end{cases}, \quad (2)$$

$$x'_A = \sqrt{(x_A - x_{ES})^2 + (y_A - y_{ES})^2} \cos(\beta - \alpha), \quad (3)$$

$$y'_A = \sqrt{(x_A - x_{ES})^2 + (y_A - y_{ES})^2} \sin(\beta - \alpha). \quad (4)$$

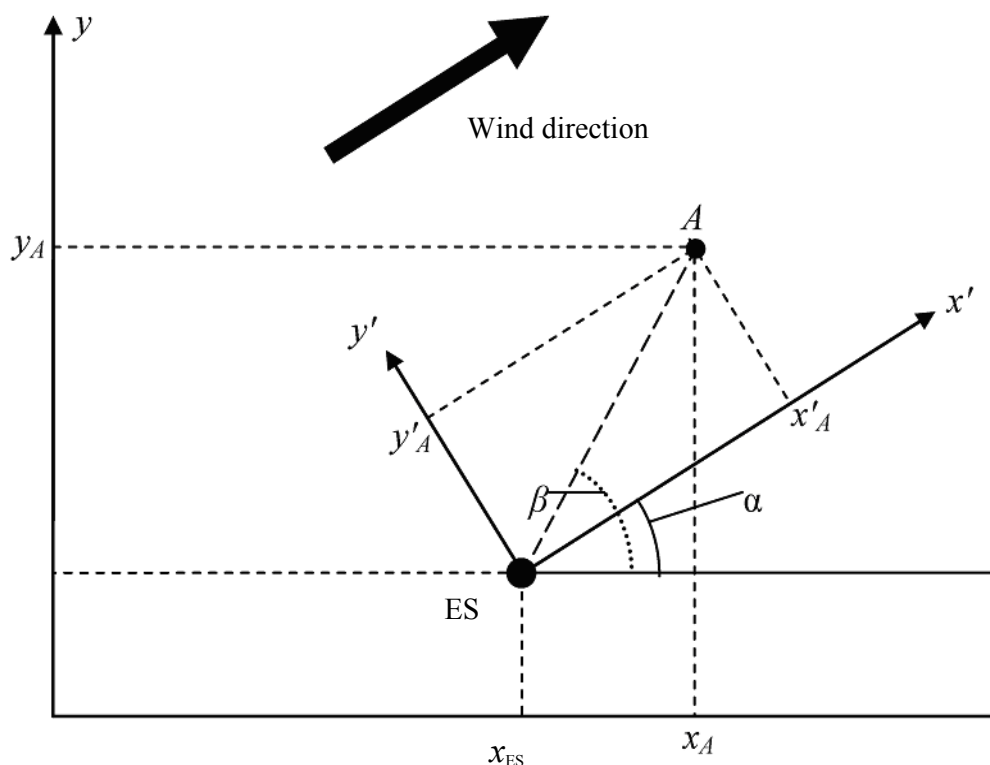


Fig. 2. The scheme of coordinates transformation for calculation of ground-level concentrations of pollutants by OND-86 technique

Thus, the developed model of technique coordinates reduction to geographic coordinates and in opposite direction allows to use the existing techniques in GIS. In developing the software package for calculation applying GCD-86 technique was used by the programming language Visual Basic for Application of GIS-based ArcGis 9.1 (ArcMap, 3D-Analyst) was used. The developed software package for calculation applying GCD-86 technique, as the superstructure of GIS can calculate the surface concentrations of pollutants at the given territory for many sources of pollution, taking into account wind speed and direction. In this case the input data for the calculation are automatically exported to the program from the external database on SQL-query. The simulation results can be presented in the form of concentration fields, which are displayed on the map of the area by color shading (Fig. 3).

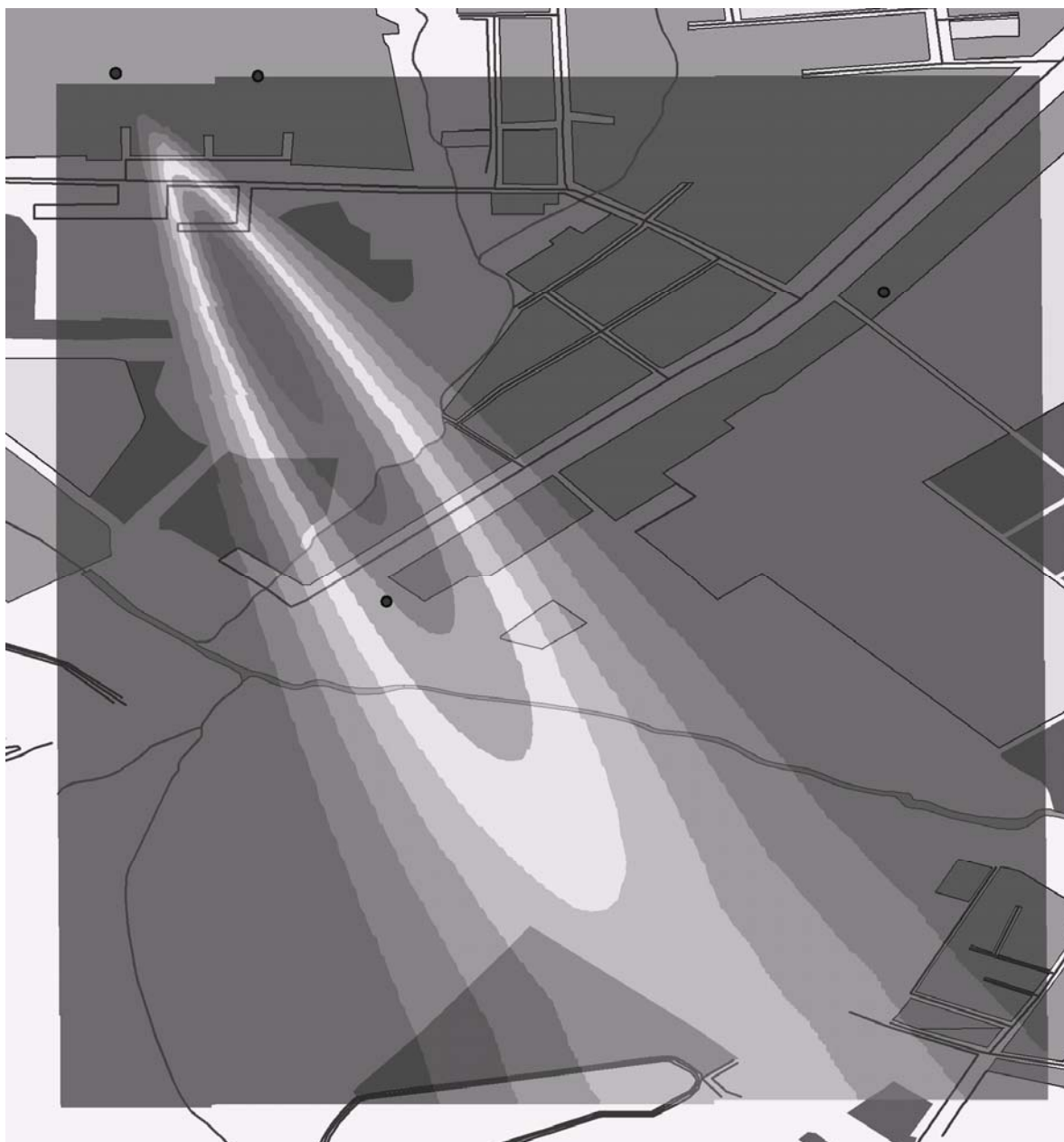


Fig. 3. The result of the pollutants propagation modeling

Conclusions. The proposed approach to modeling the pollutants spread in the surface layer of the atmosphere allowed to adapt officially acting OND-86 technique for application in GIS. The model intended for performing calculation and their visualization can be used to solve other problems of air quality management using other methods and models of pollutants spreading. Thus, the developed software package for calculation using OND-86 technique can be used by institutions and organizations (e.g. Ministry of Emergency situations), after adaptation for certain purposes calculation technique. In general, the research confirmed in practice that the calculation of ground-level concentrations of pollutants using GIS allow to evaluate comprehensively the impact of many sources of emissions on the environment for decision-making and control in the sphere of air protection.

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