Computer system for prediction of atmospheric gas plumes from technogenic and lithospheric sources

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A computer system developed by the authors is described, which allows one to calculate propagation of industrial emissions based on various models comprising reliable data on spatiotemporal distribution of admixtures in the atmosphere. The system's interface is described. The system is shown to estimate the behavior of admixtures under various atmospheric conditions and to analyze the calculated results on choosing the most optimal model fitting the particular conditions.

Introduction

Atmospheric pollution is characterized by great spatiotemporal inhomogeneity caused by location of the emission sources, their intensity, and the change of weather conditions and regime of emissions into the atmosphere. The processes in the atmosphere are too diverse and complex and the number of determining factors is quite great, so that, in addition to organization of the air pollution observation network, mathematical modeling is needed of the processes of spreading of the contaminants from their sources on the basis of the theory of turbulent diffusion.[1,2] Based on it, the building sites, efficient arrangement of enterprises and houses are selected, harmful emissions are normalized in order to provide for necessary hygienic and ecological conditions.

In this connection, it is urgent to develop an automated system of forecasting the atmospheric pollution on the basis of the models of propagation of emissions from industrial enterprises, which provide for the most reliable data on the spatiotemporal distribution of harmful admixtures in the atmosphere. Such a system should meet some principal requirements:

a) it should be independent of carrier, i.e., to be easily transferable for use on computer with different operation systems;

b) it should have a friendly interface which provides for the use of the system by users with different level of computer knowledge.

c) it should allow to use different models for calculation the admixture dispersal in the atmosphere, each of which has its own peculiarities, its own area of applicability, etc.

This paper describes a computer system developed by authors, which realizes the possibility of calculating the dispersal of admixtures on the basis of different models described below.

1. Review of the models of forecasting the atmospheric pollution

Let us briefly consider the principal models of the admixture dispersal in the atmosphere, which are used in the described computer system. One of them is mainly related to empirical-statistical analysis of the pollutants dispersal in the atmosphere using interpolation models mainly of the Gaussian type (diffusion Gaussian model). Another one uses the solution of the turbulent diffusion equation (Berlyand diffusion model). The third one is based on the statistical theory of turbulent diffusion (regional trajectory model).

1.1. Gaussian model (GM)

The formulas of Gaussian distribution of concentration obtained on the statistical basis are widely used for description of the admixture dispersal in the atmosphere. One of the first papers was written by Satton, where the concentration of an admixture at the point (x, y, z) from the source placed at the coordinate origin, is presented, in the general case, by the following formula[2]:

$$P_y = \frac{1}{\sigma_y\sqrt{2\pi}} \exp(-y^2/2\sigma_y^2) \qquad (1)$$

and analogous functions P_x and P_z related to the coordinates x and z. Here σ_y^2 is the variance of the distribution of the admixture along the y direction. By setting a certain form of the Lagrange correlation function for concentrations and using the Taylor theorem on the relation of this function to σ_i, Satton obtained that $\sigma_i = \frac{1}{2} r_i^2(\bar{u}, t)^{2-n}$, where r_i are the coefficients (i = 1, 2, 3 correspond to x, y, and z, respectively), $\bar{u}$

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is the height mean wind velocity. For an instantaneous source, t is the time after start of the source operation, and for a continuously operated source it is supposed that $t = x/\bar{u}$. Satton also showed that the power law for the change of the wind velocity with height must be fulfilled for the form of correlation function he selected.

The engineering technique, which is the development of the Satton method,[2] is now the most widespread in the USA and West European countries. According to Ref. 2, distribution of an admixture from a point source of the intensity M, in g/(m^2 · s), situated at the height H at the point (0, 0, H) has the form

$$C(x, y, z) = \frac{M}{2\pi u \sigma_y \sigma_z} \times$$

$$\times \left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right] \exp\left(-\frac{y^2}{2\sigma_y^2}\right), \quad (2)$$

where $\sigma_y = \sigma_y(x)$; $\sigma_z = \sigma_z(x)$ are horizontal and vertical variances of the admixture content, respectively.

Input parameters in this technique are the standard deviations (variances) of the displacement of particles of an admixture along the directions perpendicular to the wind σ_y and σ_z and the wind velocity u (in m/s) at the height of the source H (in m). To determine the parameters σ_y and σ_z, classifications of stability of the near-ground air layer are usually used. According to Pasquill,[4] six classes are accepted: the classes 1, 2, and 3 are related, respectively, to strong, moderate, and weak instability, 4 represents equilibrium (indifferent) state, 5 and 6 are weak and moderate stability. Certain values of the wind velocity, degree of insolation, and time of day (Table 1) correspond to each class. The values of variances as functions of longitudinal coordinate are often shown in graphical form and are called Pasquill–Gifford curves.[2] These curves are regularly reconsidered by the Environmental Protection Agency of the USA taking into account new theoretical and experimental data.

Table 1. Classes of stability by Pasquill[1,4]

Wind velocity at the height of 10 m, m/s	Degree of insolation in the daytime			Cloud fraction in the nighttime	
	Strong	Moderate	Weak	10 (total) or > 5 (lower)	< 4 (lower)
< 2	1	1–2	2	–	–
2–3	1–2	2	3	5	6
3–5	2	2–3	3	4	5
5–6	3	3–4	4	4	4
> 6	3	4	4	4	4

The values $\sigma_y(x)$, $\sigma_z(x)$ for $10^2 < x < 10^4$ m are presented in the following form (Briggs relationships):

$$\sigma_y = a_1 x(1 + b_1 x)^{-1/2}, \quad \sigma_z = a_2 x(1 + b_2 x)^{c_2}.$$

The values of the corresponding coefficients a_i, b_i ($i = 1, 2$) and c_2 for calculating $\sigma_y(x)$ and $\sigma_z(x)$ under conditions of a flat underlying surface[1] are shown in Table 2.

Table 2. Values of the coefficients a_i, b_i (i = 1, 2), and c_2

Class by Pasquill	σ_y, m		σ_z, m		
	a_1	b_1	a_2	b_2	c_2
1	0.22	10^{-4}	0.20	0	0
2	0.16	10^{-4}	0.12	0	0
3	0.11	10^{-4}	0.08	$2 \cdot 10^{-4}$	0.5
4	0.08	10^{-4}	0.06	$15 \cdot 10^{-4}$	0.5
5	0.06	10^{-4}	0.03	$3 \cdot 10^{-4}$	−1
6	0.04	10^{-4}	0.016	$3 \cdot 10^{-4}$	−1

The values of the corresponding coefficients a_i, b_i ($i = 1, 2$), and c_2 at $10^2 < x < 10^4$ m for the urban conditions are shown in Table 3.

Table 3. Values of the coefficients a_i, b_i (i = 1, 2), and c_2 for a city

Class by Pasquill	σ_y, m		σ_z, m		
	a_1	b_1	a_2	b_2	c_2
1–2	0.32	$4 \cdot 10^{-4}$	0.24	10^{-3}	0.5
3	0.22	$4 \cdot 10^{-4}$	0.20	0	0
4	0.16	$4 \cdot 10^{-4}$	0.14	$3 \cdot 10^{-4}$	−0.5
5–6	0.11	$4 \cdot 10^{-4}$	0.08	$1.5 \cdot 10^{-4}$	−0.5

In investigating the dispersal of an admixture emitted from the source, for example, from the stacks of industrial enterprises, one should keep in mind that, due to the initial pulse of emission and the effect of Archimedes force, the admixture is lifted to some additional height ΔH. This means that, when calculating dispersal of the admixtures, one should use some effective height of the source, which is the sum $H + \Delta H$.

To calculate the initial lifting of the exhaust ΔH, an approximate formula[4] is used:

$$\Delta H = \frac{3.75\ \omega_0 R_0}{U} + \frac{1.6\ g V_1\ \Delta T}{T_a\ U^3},$$

where ω_0 is the initial velocity of the gas emission, R_0 is the radius of the source stack mouth, m; T_a is temperature of the ambient air, K; ΔT is the difference of temperatures of the emission and the ambient air, K; $V_1 = \pi R_0^2\ \omega_0$ is the volume of gases emitted in a unit time; U is the wind velocity at the height of vane (10 m), g is acceleration due to gravity, m/s^2.

For the case of equilibrium stratification of the atmosphere (the 4th class of stability) one usually uses the formula

$$\Delta H = \frac{1.5\ \omega_0 R_0}{u}\left(2.5 + \frac{3.3\ g R_0\ \Delta T}{T_a\ u^2}\right).$$

For example, in the case of stable conditions (5th and 6th classes) the following formulas are applied to calculations:

a) at the wind (> 2 m/s) $\Delta H = 2.6 \left(\frac{F_0}{uS}\right)^{1/3}$,

b) at calm $\Delta H = 5.3\, F_0^{1/4}\, S^{3/8} - R_0$,
where

$$S = \frac{g}{T_a} + \left(\frac{dT_a}{dz} + 0.01\right),$$

the value $\frac{dT_a}{dz}$ in this case is the vertical gradient of temperature, K/m, $F_0 = (g\Delta T/T_a)\omega_0 R_0^2$.

The presence of inversion of atmospheric temperature (i.e., increase of temperature with height) is determined as the stable stratification (5th and 6th classes of stability) and supposes the use of the Briggs relationships for different atmospheric conditions.

1.2. Berlyand model (BM)

This approach is the most universal as compared with the former one, because it allows one to investigate the dispersal of admixtures from sources of different type at different characteristics of the medium. One can use the model only supposing delta-correlation of wind velocity fluctuations.

In the general case, the problem on air pollution forecast can mathematically be reduced to solution under certain initial and boundary conditions of the differential equation[3,4]:

$$\frac{\partial \bar{u}_\alpha q}{\partial x_\alpha} + \frac{\partial q}{\partial t} = \frac{\partial k_{\alpha\beta}}{\partial x_\alpha}\left(\frac{\partial q}{\partial x_\beta}\right), \qquad (3)$$

where $x_{\alpha\beta}$ are the generalized coordinates, $\bar{u}_\alpha$ and $k_{\alpha\beta}$ are the components of the mean velocity of the admixture transfer and turbulent exchange coefficient, $\alpha, \beta = 1, 2, 3$.

In the case when

$$k_z(z) = k_1\left(\frac{z}{z_1}\right)^m,\ u(z) = u_1\left(\frac{z}{z_1}\right)^n,\ k_y(z) = k_0 u(z),$$

where u_1 is the wind velocity at the height z_1, k_1 is the turbulent exchange coefficient at the height z_1, k_0 is determined by the condition $k_y(h) \approx k_z(h)$, h is the height of the near-ground layer, analytical solution of the Eq. (3) (Ref. 3) has been derived:

$$q(x, y, z) = \frac{M(zH)^{(1-m)/2}\, z_1^m}{2(2+n-m)\, k_1 \sqrt{\pi k_0 x^3}} \exp\left[-\frac{y^2}{4k_0 x}\right] \times$$

$$\times \exp\left[\frac{u_1 z_1^{m-n}\,(z^{2+n-m} + H^{2+n-m})}{k_1\,(2+n-m)x}\right] I_{\frac{1-m}{(2+n-m)}}(Z);$$

$$Z = \left(\frac{2u_1\,(zH)^{(2+n-m)/2}\, z_1^{m-n}}{(2+n-m)^2\, k_1\, x}\right), \qquad (4)$$

where $I_{\frac{1-m}{(2+n-m)}}(Z)$ is the modified Bessel function.

Formula (4) is usually used in our country for calculation of air pollution. The parameters k_1 and h are not set by their mean values, but are determined depending on the temperature stratification. This model uses approximation of the mean statistical profiles $k_z(z)$, $k_y(z)$, $u(z)$ by power-law dependences, i.e.,

$$u(z) = u_1(z)\left(\frac{z}{z_1}\right)^n,\ k_y(z) = k_0 u(z);$$

$$k_z(z) = \begin{cases} k_1 z/z_1; & z < h, \\ k_1 h/z_1; & z \ge h. \end{cases}$$

Input parameters of the model are z_0, L; z_1 is the height at which the wind velocity is equal to u_1. Let us use the following formulas[4] for determination of k_1, h, and k_0:

$$k_1 = \frac{\chi^2 u_1}{\ln(z_1/z_0)} LJ(z_1/L),\ \chi = 0.4;$$

$$J(x) = \begin{cases} x(1 + 0.54\,|x|^{0.8}); & x < 0, \\ \dfrac{x}{1 + 0.9x}; & 0 < x < 1, \\ 0.53; & x \ge 1; \end{cases}$$

$$h = \frac{0.05k_1}{z_1\, 10^{-4}};\quad k_0 = \frac{k_z(h)}{u(h)};\quad L = \frac{0.1T_a\, u_1}{g\Delta T}\,\frac{\ln(z_3/z_2)}{\ln(z_1/z_0)}$$

is the Monin–Obukhov scale.

Let us choose the index n from Table 4 (Ref. 4) using the class of stability and the value of roughness of the underlying surface z_0.

Table 4. Class of stability

z_0, m	Class of stability					
	1	2	3	4	5	6
0.01	0.05	0.06	0.06	0.12	0.32	0.53
0.1	0.08	0.05	0.11	0.16	0.34	0.54
1.0	0.17	0.17	0.2	0.27	0.38	0.61
3.0	0.27	0.28	0.31	0.37	0.47	0.65

To calculate the concentration by this method, one usually uses formula (4).

1.3. Regional trajectory model of admixtures transport (RM)

Modern stage of the development of ecological investigations is characterized by increased attention to the problem of optimal estimation of spatial distribution of the contaminants emitted into the atmosphere due to industrial emergency accidents. Emissions of the products of nuclear fission, which appear most often at accidents of atomic electric power plants, radiochemical plants, and storehouses of radioactive wastes, are the greatest hazard. Important peculiarity of these accidents is the possibility of emergency emissions of radionuclides into the atmosphere in one volley.

As the existing network of ecological stations doest not allow one to monitor the atmospheric pollutions due to its low dense coverage, in order to provide for ecological safety, it is necessary to be able to calculate the admixture dispersal from the emission sites (sources) and their concentration at different points of space. To do it, one usually uses different theoretical models of the admixture transport realized on a computer. One of such models is considered below, namely, the trajectory model of admixture transfer.

Equation of the model for the boundary layer of the atmosphere is derived by means of integration over height from $z = 0$ to $z = H$ of the admixture transport equation[2,4]:

$$\frac{\partial s}{\partial t} + u\frac{\partial s}{\partial x} + v\frac{\partial s}{\partial y} + w\frac{\partial s}{\partial z} + \frac{\partial w_a^s}{\partial z} =$$

$$= \frac{\partial}{\partial x} k_1 \frac{\partial s}{\partial x} + \frac{\partial}{\partial y} k_1 \frac{\partial s}{\partial y} + \frac{\partial}{\partial z} k \frac{\partial s}{\partial z} + \varepsilon_0 \qquad (5)$$

under the boundary conditions:

$$\text{at } z = 0\ (z = z_0)\quad k\frac{\partial s}{\partial z} - w_a^s = \beta s - f_0,$$

$$\text{at } z = H(H_1)\quad w = w_H,\quad k = k_H, \qquad (6)$$

where s is the total concentration of the admixture, w_a is the vertical velocity of the a admixture itself, β is the rate of dry absorption of the admixture by the ground surface, k_1 is the turbulent coefficient at horizontal motions, k is the turbulent coefficient at vertical motion, k_H and w_H are the turbulent coefficient and vertical velocity of air at the height $z = H$, ε_0 is the rate of production or destruction of the admixture caused by the emission of admixture from the sources in the layer, removal of the admixture by atmospheric precipitation, and chemical transformations, f_0 is the rate of emission of the admixture into the atmosphere by ground-based sources.

Resulting from integration of the admixture transport equation (5) and taking into account boundary conditions (6), after introducing the mean for the boundary layer values, the solution is sought in the form

$$s(x, y, t) = P(x, y, t)\ s'(x, t).$$

For P it is accepted that

$$P(x, y, t) = \frac{1}{\sqrt{2\pi d_0 x}} \exp(-y^2/4d_0 x),$$

where d_0 is the constant $[d_0 = k_1(y)/u(y)]$. The equation for s' is solved numerically by means of the change of integration over time for integration over the trajectory. Let us approximate this equation as follows:

$$s'^{(n)} = s'^{(n-1)} - \Delta t \sigma s'^{(n,\, n-1)} + \Delta t \frac{1}{P} \varphi^{(n,\, n-1)},$$

where n is the number of the time step ($n = 1, 2, \ldots$); Δt is the time step; $s'^{(n-1)}$ is the value s' at the moment $n - 1$; $s'^{(n)}$ is the same value at the next moment n.

These moments correspond to the initial and final points of the trajectory during the time step Δt. According to implicit procedure of calculation

$$s'^{(n)} = \frac{1 - \sigma\Delta t/2}{1 + \sigma\Delta t/2} s'^{(n-1)} + \frac{\Delta t/2}{1 + \sigma\Delta t/2}\left[\frac{\varphi^{(n)}}{P} + \frac{\varphi^{(n-1)}}{P}\right];$$

$$\varphi = \varphi(x, y, t) = F(x, y, t) + \frac{1}{H} f_0(x, y, t);$$

$$\sigma = \sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5 + \sigma_6.$$

Here F is the rate of emission of the admixture by elevated sources, $\sigma_1 = \alpha_0\beta/H$; $\sigma_2 = \alpha^* I$, where I is the intensity of precipitation, α^* is the coefficient, σ_3 is the coefficient, by means of which chemical transformations of admixtures are taken into account; $\sigma_4 = (\alpha_0 - \alpha_H) \times k_H/H^2$; $\sigma_5 = \alpha_H w_H/H$; $\sigma_6 = \alpha_H w_a/H$ ($\alpha_0 = s_0/s$; $\alpha_H = s_H/s$, where s_0 and s_H are the values of s at $z = 0$ and $z = H$) are the semi-empirical coefficients determined based on the data on the vertical profile of pollutions.

2. The structure of the computation system

The computer system is oriented to a non-professional user and operates on an IBM PC under the control of WINDOWS 95/98/NT operation system. The software of the computer system was realized by means of the object-oriented language Delphi 5.0. The use of this programming medium allowed us to supply the system with a suitable graphical interface with a menu system, possibility of representing the calculated results by plots and tables, access to data file, high speed of calculations, and possibility of further extending and changing the calculation algorithms.

The computer system makes it possible:

– to select the type of calculations for each model; to introduce and correct the input parameters for calculations, to select input parameters from table used as default;

– to calculate the near-ground concentration of admixtures as well as the concentration of admixtures in a horizontal plane at an arbitrary altitude, to calculate the concentration of admixtures in the atmospheric column at an arbitrary distance from the emission source (for the Gaussian model and Berlyand model);

– to calculate the distribution of maximum concentration of admixtures in the atmosphere (for the Gaussian and the Berlyand models);

– to calculate the distribution of concentration along the trajectory of its transport with a time step (for the regional model);

– to present the calculated results by plots (for all models);

– to save in file, to copy to the clipboard, to print the plots of calculated results (for all models);

– to change the scale on the abscissa axis;

– to calculate the maximum value of the concentration of an admixture, distance and height at which it is reached (for the Gaussian and the Berlyand models);

– to present the calculated results in tables and to save them in the working file (for the regional model).

The structure diagram of the software environment of the computer system that shows the principal codes and subroutines is shown in Fig. 1.

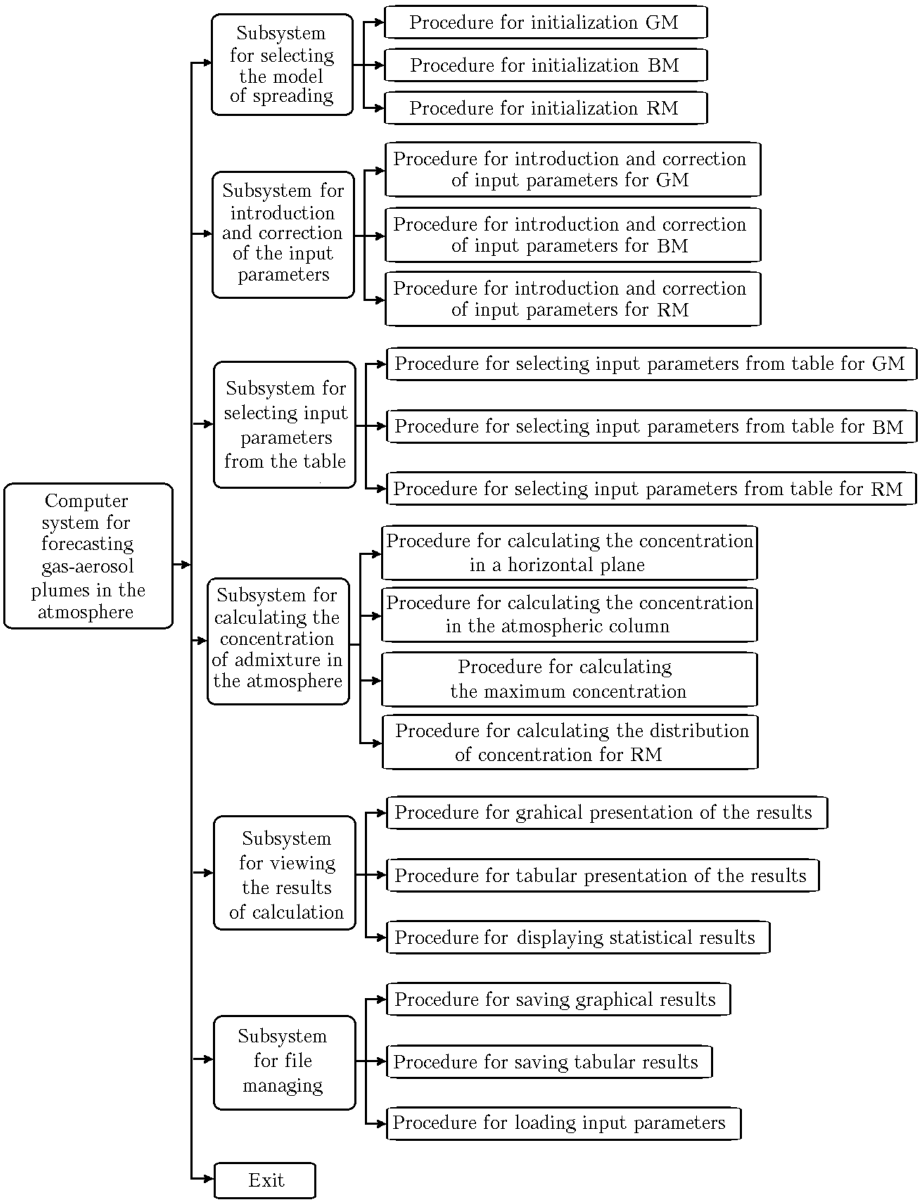


Fig. 1. Structure diagram of the computer system.

2.1. Description of operation of the computer system

The loading module POLUTION.EXE serves for loading the program.

The working window of the program envelop after loading the computer system is shown in Fig. 2.

After loading the program, the following procedures are performed:

– initialization, which selects the method, by means of which the calculations will be performed (Gaussian model is used as default);

– loading the table of input parameters for operation of the calculation method (table T1.Db by default);

– assignment of specific value to the input parameters (by default, the values are read from the first record of the open table of parameters);

– selection of the type of calculation (by default, the near-ground concentration of admixture is calculated).

The button "Calculate" (see Fig. 2) serves for starting the calculation process, resulting from which the plot, the value of the maximum concentration, and the distance from the source, at which it is reached, are displayed. The editable box "Distance" serves for exact setting the distance, up to which the calculation will be performed. If the value of this field has not been changed (the value 0 is assigned by default), the program calculates up to the maximum possible distance of 6000 m. Then the working window of the program after calculating the near-ground concentration of admixture by means of the Gaussian model is shown (the result is obtained by pressing the button "Calculate" just after loading the program without any changes).

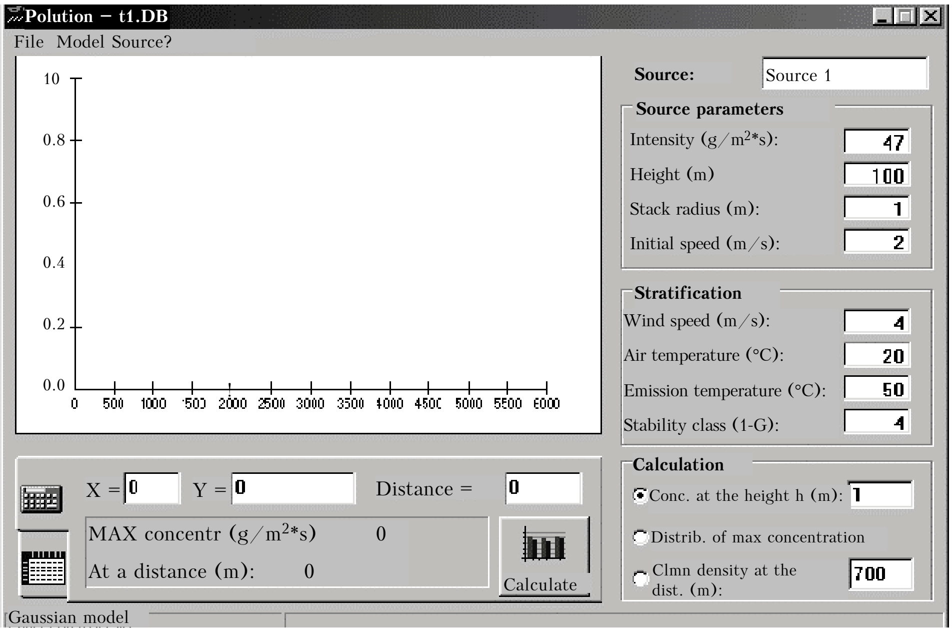


Fig. 2. Working window of the program, where the distances are set in meters.

The height of the horizontal plane, for which the calculations are performed, is set in the editable box opposite to the selected type of calculation (in this case the value is equal to 1). The type of calculations is selected by "Calculation" radio buttons in the right lower corner of the window of application. The windows of applications after calculating the vertical distribution of the concentrations of admixtures in the atmosphere by different methods are shown in Figs. 3–6.

The window of application after calculating the distribution of the concentration of admixture over the atmospheric column (Gaussian model) at the distance of 700 m, which is set in the editable box opposite to the selected type of calculation, is shown in Fig. 3. The value of the maximum concentration and the height at which it is reached are displayed.

The editable box "X" in the considered example contains the value of height (100 m), for which the value of the concentration of an admixture is calculated and then placed to the field "Y".

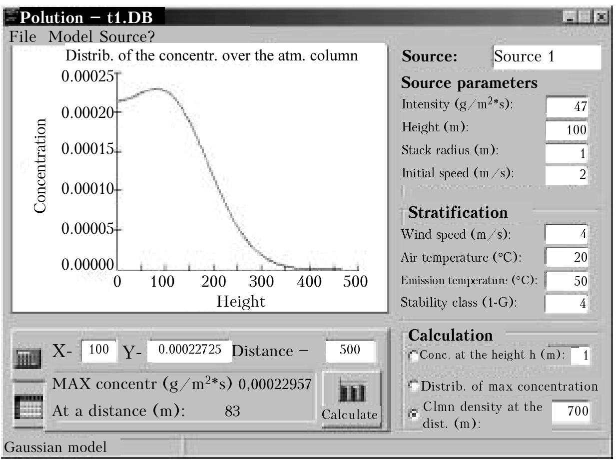


Fig. 3. Concentration of admixture in the atmospheric column at the distance of 700 m from the source (Gauss model).

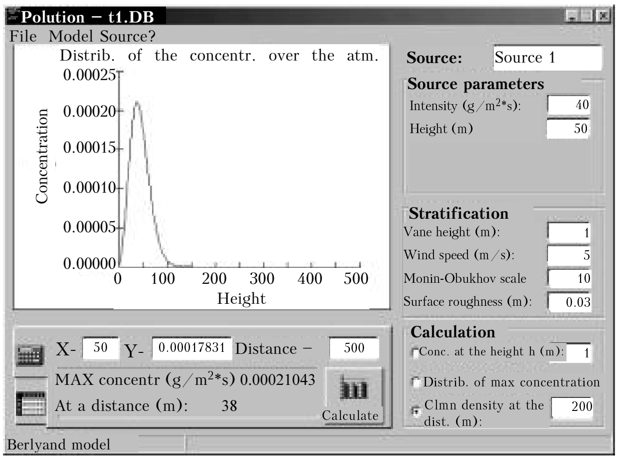


Fig. 4. Concentration of admixture in the atmospheric column at the distance of 200 m from the source (Berlyand model).

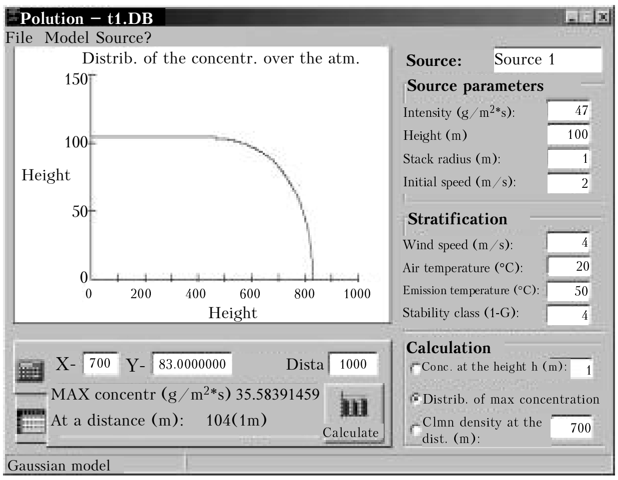


Fig. 5. Distribution of the maximum concentration of admixture (Gaussian model).

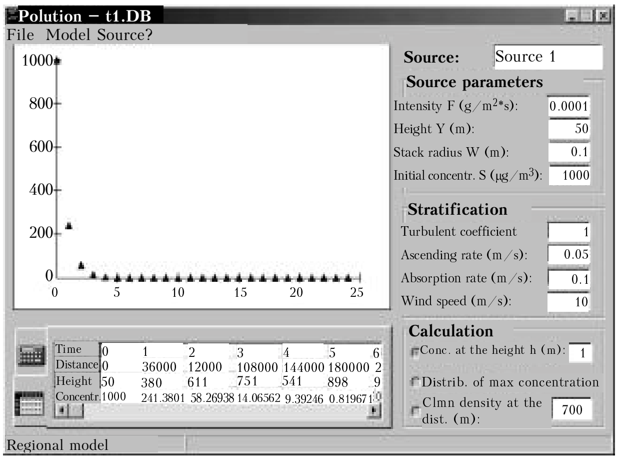


Fig. 6. Presentation of the results of calculations using the regional (trajectory) model.

The maximum value of concentration, height, and distance, at which it is reached, are shown in Fig. 5.

The editable box "X" serves for input of an arbitrary distance within the limits of the calculated distance in order to obtain the corresponding value of the function at the point X at the abscissa axis and placing it to the box "Y" (in this case the result is the height, at which the maximum value of the concentration of the admixture is reached).

The window of application after selecting the Berlyand model and calculating the near-ground concentration of admixture is shown in Fig. 4.

The editable boxes have here the same functions as for the Gaussian model considered above, only the list of input parameters has been changed.

In the case of selecting the regional model (Fig. 6), the only type of calculations is used, namely, calculation of the distribution of concentration of an admixture on the scale of the region with the time step of 1 hour (total time of calculations is 24 hours), so the section "Calculation" becomes unavailable. After pressing the button "Calculate" applied to the regional model the window of application takes the view shown in Fig. 6. In order to get access to the table of calculated results, it is necessary to select the bookmark with the picture of the table. The table of calculated results is shown in Fig. 6.

The model of an admixture dispersal in the atmosphere, on the basis of which the calculations are performed, is selected in the menu "Model" (Fig. 7). The selected model for calculations is ticked, and the name of the model is displayed in the state string of the window of the corresponding application.

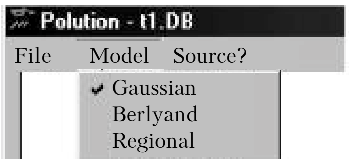


Fig. 7. Menu "Model."

If it is necessary to save the table of calculated results, one should choose option "Save the table of results" in the menu "File" (Fig. 8).

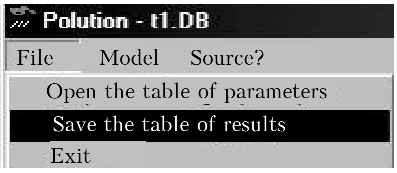


Fig. 8. Option "Save the table of results."

After selecting this option, the standard window of saving data files appears. The only requirement to saving data file is to indicate the file extension ".db".

In order not to enter the input parameters manually, it is necessary to select corresponding option of the menu. External tables are suitable, because the parameters once put in the table (for example, parameters of the source, which should be preliminary selected, Fig. 9) can be used many times in the subsequent work.

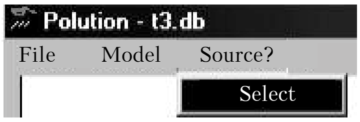
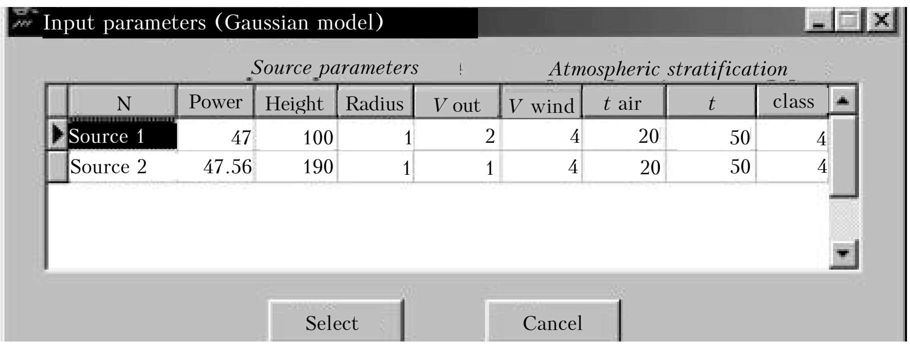


Fig. 9. Option "Select source."

As every model of calculation of the admixture dispersal in the atmosphere has its own peculiarities, the specific table with its own set of input parameters is used in every specific case. Figure 10 shows an example of the list containing the table of input parameters of the Gaussian model.



N	Power	Height	Radius	V out	V wind	t air	t	class
Source 1	47	100	1	2	4	20	50	4
Source 2	47.56	190	1	1	4	20	50	4

Fig. 10. Table of the input parameters for the Gaussian model.

Edition (deleting records, adding new records) of input parameters in these tables and saving changes are performed according to the generally accepted rules of the work with tabulated data. When pressing the button "Select" on the shown form, all parameters from the corresponding record become the input parameters and are displayed in the main (initial) form of the application.

If it is necessary to use the input parameters from other external tables, one should open menu "File" and select option "Open the table of parameters" (Fig. 11).

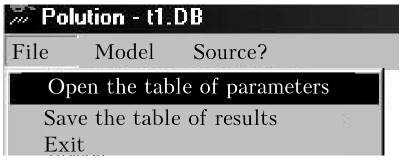


Fig. 11. Menu "File."

After selecting the option "Open the table of parameters," the standard window of opening files appears. If selecting the file with extension ".db" that contains the list of parameters for the specific model, the table used by default will be replaced by the selected table, and the values of current parameters will be taken from the first record of the opened table.

Let us consider service abilities of the computer system, which enable one to change the scale and the view of the plots. Control of these functions is performed by means of the context menu, which appears after pressing the right button of the mouse if the cursor is situated within the plot. The submenu "Scale on X" of the context menu (Fig. 12) contains the permissible scales on the *X* axis (in meters).

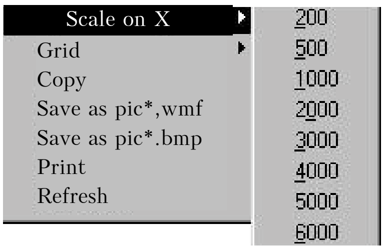


Fig. 12. Submenu "Scale on X."

The submenu "Grid" of the context menu is intended for setting and removing the vertical and horizontal grids (Fig. 13).

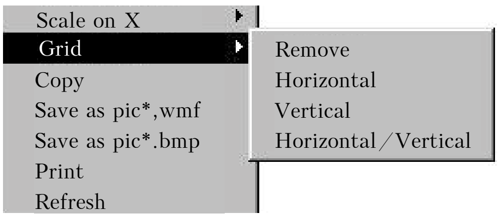


Fig. 13. Submenu "Grid."

Then the example of using the options of the submenu "Scale on X" and submenu "Grid" is shown in Fig. 14.

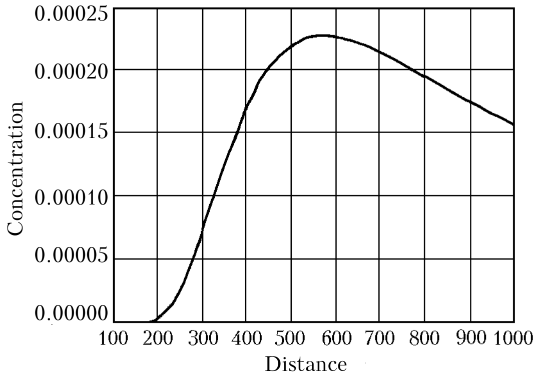


Fig. 14. View of the plot with the window scale 100 m and horizontal-vertical grid.

The option "Copy" (see Fig. 13) of the context menu serves for copying the plot in the clipboard for subsequent pasting the image from the clipboard to different documents and graphical editors.

The options "Save as pic*.bmp" and "Save as pic*.wmf" (see Fig. 12) serve for saving the plot in the external graphical file of the corresponding format. The saved files will be arranged in the current directory with the name pic*, where "*" is the number (starting from 1) of the saved file in the current session of work.

The option "Print" of the context menu (see Fig. 12) serves for output of the plot to printer. The option "Refresh" is necessary for refreshing the plot when using the regional model of spreading admixture.

In the case of selecting the column of the table of results in the page marked by the bookmark "Table" and selecting this option from the context menu, the scale on the ordinate axis will be changed taking into account the selected column in the table of results.

2.2. Results of the use of the computer system (on the basis of the Gaussian and Berlyand models)

Figures 15 and 16 show the results of operation of the computer system for calculation of spreading of admixture for the source of emission with the following parameters: stack height 20 m, diameter of the stack mouth 2 m, the speed of the admixture emission 4 m/s on the basis of the Gaussian model. The dependence of the behavior of the emission of admixture on the atmospheric stratification is seen in Fig. 15. The height of the level of the maximum concentration does not change up to the distance of 400 m from the source, then, the higher is the class of stability of the atmosphere, the slower sedimentation of the emission occurs (see Fig. 15), hence, the maximum concentration of admixture at the ground level is less significant (see Fig. 16) and is reached at far longer distances from the source. At the same time, near-ground concentration at great distances from the source is the greater, the higher is the class of stability of the atmosphere (see Fig. 16).

Figure 17 shows the dependence of the near-ground concentration at different wind speed. The higher is the wind, the lower is the peak of maximum concentration and the faster the decrease of the concentration occurs at significant distances.

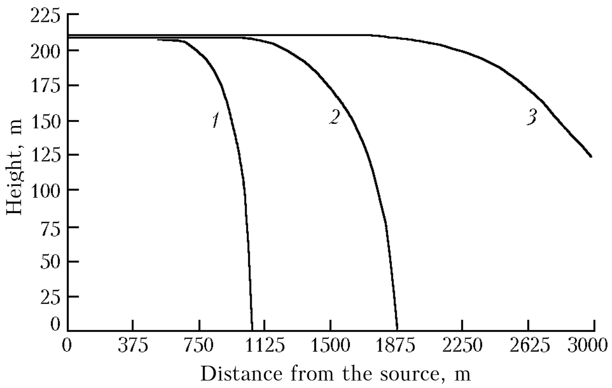


Fig. 15. Height dependence of the level of the maximum concentration as a function of the distance from the source for different classes of stability of the atmosphere (wind velocity 4 m/s): class 3 (*1*); 4 (*2*); 5 (*3*).

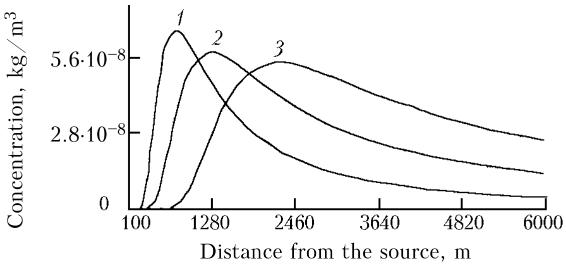


Fig. 16. Distribution of the near-ground concentration of an admixture for different classes of stability of the atmosphere (wind velocity 4 m/s): class 3 (*1*); 4 (*2*); 5 (*3*).

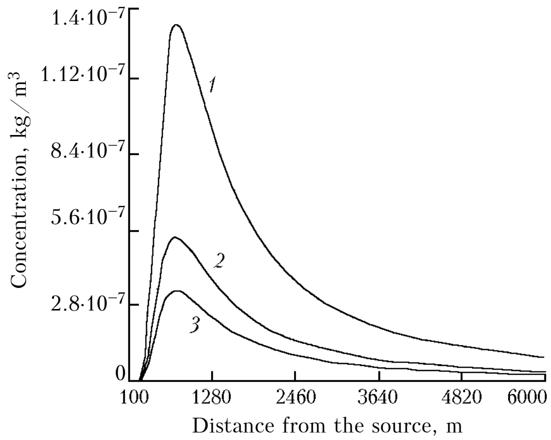


Fig. 17. Distribution of the near-ground concentration of an admixture at different wind speed (class of stability 3): 2 (*1*); 5 (*2*); 8 m/s (*3*).

Calculations of the concentration of the admixture in the atmospheric column were performed using Berlyand model at analogous parameters of the emission source. The distance from the emission source changed from 10 to 600 m (Fig. 18).

It is seen from Fig. 18 that, as the distance from the source increases, the spread of the emission occurs and, hence, the maximum concentration in the emission plume decreases, what agrees with the results calculated using Gaussian model.

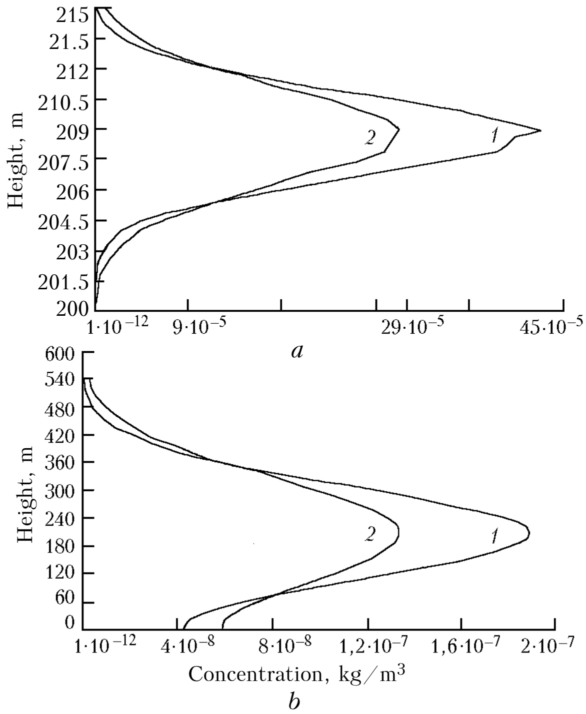


Fig. 18. Distribution of the concentration of admixture in the atmospheric column at fixed distance from the source: 10 (*1*); 12 m (*2*) (*a*); 500 (*1*); 600 m (*2*) (*b*).

Conclusion

The computer system makes it possible to immediately calculate the behavior of admixtures using the aforementioned models under different atmospheric conditions. As it is possible to use different models for estimation of the concentration of admixture during one session, it allows one to perform comparative analysis of the calculated results aimed at selection of most optimal model for the specific conditions of the emission.

Great number of calculations carried out when testing the described system have shown that all models approximately coincide in the estimate of the maximum value of the near-ground concentration. However, the models give essential difference in the shape of the spatial distribution of the concentration, in particular, positions, where the maximum concentration is reached, differ by 2–4 times, and the width of distribution in the cross direction is significantly different.

The computer system can be used for solving many problems of ecological monitoring of the atmosphere. The system with the WIMP interface is intended for specialists with different level of computer knowledge.

References

1. *Atmosphere.* Handbook (Gidrometeoizdat, Leningrad, 1991), 509 pp.

2. F.T.M. Nieuwstadt and H. van Dop, *Atmospheric Turbulence and Air Pollution Modeling* (Reidel, Dordrecht, 1982).

3. M.E. Berlyand, *Modern Problems of Atmospheric Diffusion and Atmospheric Pollution* (Gidrometeoizdat, Leningrad, 1975), 436 pp.

4. M.E. *Berlyand, Forecast and Regulation of the Atmospheric Pollution* (Gidrometeoizdat, Leningrad, 1985), 272 pp.