Information system of region ecological monitoring in case of pollution of atmosphere by industrial emissions

Zaurbekova G.N.

PhD student
Al-Farabi Kazakh National University
Almaty, Kazakhstan
E-mail: guzzzya_92@mail.ru

Abstract
The developed information system uses a wide range of mathematical models and application programs of transmission and dissipation of harmful substances in case of real atmospheric processes: mathematical models, block diagrams and application programs of transmission process of polluting substances in atmospheric boundary layer with nonstationary upper boundary; mathematical models, block diagrams and application programs of transmission process of harmful impurities in ground layer of the atmosphere taking into account lower boundary of inverse; numerical models of lower (boundary and ground) atmosphere layers. Computing experimental calculations are conducted for creation of methods of correction, control and prediction of ecological situation of the technopolis region.

Key words: ATMOSPHERIC PROCESSES, POLLUTION OF ATMOSPHERE, ATMOSPHERIC BOUNDARY LAYER, GROUND LAYER OF ATMOSPHERE, MATHEMATICAL SIMULATION OF ATMOSPHERE POLLUTION, INFORMATION SYSTEMS OF ECOLOGICAL SITUATION MONITORING

For research of the local atmospheric processes taking place in boundary layer, the mathematical model based on system of equations of hydrothermodynamics is used. Due to rather small horizontal scales (50x50 km) of the considered mesometeorological processes, let us put the system of equations of hydrothermodynamics in Cartesian coordinate system x, y, z. The following equations are taken as initial: motion, continuity, state, heat inflow, specific humidity, where velocity vector, temperature, potential temperature, pressure, density, specific humidity, tensor of viscous tension of flow, heat and moisture are functions of coordinate and time obtained in the second section for real atmospheric processes.

The universal gas constant, condensation heat, specific heat capacity of air in case of constant pressure, radiation component of heat inflow, thermal equivalent of operation, gravitational acceleration, Coriolis parameter, liquid phase formation rate determined within the accuracy of turbulent members and expressed via dry and moist adiabatic gradients take part in certain types of heat and moisture flows, tensor of viscous tension, environment condition.

In order to obtain the harmonized system for local atmospheric motions, meteorological fields are presented in the form of sum of background value of field; and also their deviation from background value is shown. Substituting the value of meteorological fields in the form of sum of background ones (their deviations) into initial equations, dropping small members that appear owing to assumption that the relation is not enough for background, and then subtracting the appropriate equations for background fields from these equations, we obtain the initial system of equations of local atmospheric processes. Supposing that background fields within the accuracy of small items satisfied the initial systems and spatial-temporal oscillations of insignificant density, we obtain final system of equations in perturbations where convection parameters, vertical gradient of the standard atmosphere, horizontal gradients of background potential temperature and specific humidity take part.

Let us consider coupled models of dynamics of atmospheric boundary layer in interaction with thermally and orographicaly non-uniform underlying surface. For land, it is model of temperature condition of soil with the equation of heat balance on boundary with the atmosphere, and also moisture exchange model. Distribution of temperature in the soil is described by the known equation. Let us accept the equation of heat balance as conditions on the ground surface. It is known that temperature of ground air and summary evaporation of the humidified surface depend on insolation of surface activity. Distinctions in insolation of slopes depending on their expositions can cause considerable mesometeorological contrasts under conditions of orographical underlying surface. Therefore, for calculation of solar flux at a slope surface, non-standardized formula from M. I. Budyk's paper is used. In many models of atmosphere dynamics, the equations of thermal balance are used for finding of soil temperature. Thermal and physical characteristics of soil are various; therefore, temperatures over various types of the soil differ significantly even at short distances, and thus, affect the dynamics of the atmosphere in the lower layers.

The solution of the equations system of hydrodynamics at constant coefficient of turbulent interaction or turbulent viscosity shows that it is coordinated with some physically clear properties of the flux, which we are interested in, even if the thickness of boundary layer is considered as the specified external parameter. The drawback of solution is that proportionality of wind shift to speed shift of geometrical wind follows from it at any values of coefficient of turbulent interaction. The method based on the solution of the equation of turbulent energy balance is applied for completion of the equations system of atmosphere boundary with regard to vertical coefficients of diffusion; operators of horizontal turbulent interaction were calculated by tensor of viscous tension.

Necessity of various approaches use for the description of vertical and horizontal turbulent interaction is connected with the fact that in the equation of balance of turbulent energy, temperature stratification of the atmosphere is considered that is especially important for vertical interaction. Naturally, at high level of relative humidity, cloud cover is formed; therefore, atmosphere stratification is changed because of heat additional inflow generation due to condensation in some local areas in upper layers of atmosphere. Observation of mesoprocesses, which horizontal dimensions are several dozens of kilometers, show that they are followed by formation of clouds with horizontal dimensions of 5-10 km and vertical ones with about 1.5-2.5 km. In this regard, the consideration of phase transitions of moisture is necessary.

In this case, the equations system of the atmosphere boundary layer with initial and boundary conditions is solved taking into account the member of liquid phase formation. Also, it is supplemented with the equation of transfer and diffusion for specific water content. For numerical modeling of hydrometeorological mode of industrial regions, it is necessary to have value of meteoelements in the regular grid knots as initial data. Measurements are performed on the meteorological stations located irregularly throughout the territory. Therefore, there appears a problem of renewal of meteoelements values in the grid knots in accordance with their values at stations. The problem of restoration of fields structures of hydrometeoelements are solved according to V. V. Penenko's paper. It is known that extent of pollution of the atmosphere lower layers by harmful substances depends not only on technological and design data of pollution sources, but also on a number of meteorological factors, which determine the process of impurity distribution in atmosphere boundary layer. These factors are the following: wind speed, thermal stratification, area orography, character of the layering surface etc. Therefore, for more complete description of processes of diffusion transfer and impurity transformation, they need to be considered on the basis of physically abundant model which considers at least the diurnal course of dispersion variability depending on meteorological situations, orographical and thermal inhomogeneity of the layering surface. For this purpose, let us add mathematical model of transfer and transformation of impurity to the model of dynamics of the atmosphere boundary layer; and further they are solved together.

Let us analyze some results of calculations. For example, (Figure 1) isolines implement the variant with various levels of observation ($Z_1 = 10$ m, $Z_2 = 100$ m). In the upper layers of atmosphere with increase in height, the speed of wind increases and size of vortexes serving turbulent interaction also increases that leads to high level of distribution of the polluting impurity. As it was already specified, due to the specified calculation conditions, it is impossible to separate the isolines of level of units of admissible concentration limit (level 7).

Calculations of dispersion of the harmful substances which are contained in products of gas combustion in the open flare facility are conducted. Geo-ecological distribution maps of impurity with application of hydrodynamic model of the atmosphere boundary layer are created. With growth of number and power of oil and gas extraction fields, danger that concentration of the harmful substances coming to the lower layers of atmosphere can exceed maximum permissible level increases sharply. It is obvious that extent of pollution of the lower layers of atmosphere depends not only on technological and design data of industrial facilities (such as emission power, height and diameter of pipes, speed of transfer and temperature of substances which are thrown out in air, etc.), but also on those factors which determine process of impurity distribution in the atmosphere. These factors are the following: wind speed, atmosphere stratification, area orography, character of the layering surface etc. They determine the speed of transfer of harmful substances along the direction of average wind and intensity of turbulent exchange. When starting the study of processes of impurity distribution, it should be remembered that in most cases they proceed within atmosphere boundary layer. Therefore, the concept of structure of this layer, in particular, of dynamics of boundary layer and equation of transfer and diffusion of impurity, which have been stated in the first subsection of the third section, is the cornerstone of the numerical calculations stated below.

Mathematical modeling of the atmosphere boundary layer with the free upper boundary of air mass

At mathematical modeling of atmosphere boundary layer with the free upper bound of air mass, the basic mathematical models of motion of hydrodynamic mode of real atmospheric processes have been developed. Models are developed taking into account the mechanism of phase transitions of water, processes in planetary boundary layer, influence of radiation and turbulent transfers of energy, processes of condensation, changes of thermodynamic condition of the non-uniform atmosphere leading to significant change of circulation, geophysical properties of Earth and mass forces of Earth rotation and their heterogeneity, and also area orography.

In the papers [1-12]:

1. Models of inflow of heat which is important factors of dynamics of baroclinic transformations, changes of pressure in the damp atmosphere and for non-advective changes of pressure in case of absence of condensation are obtained. Predictive models of compressed atmosphere for determination of average meteorological elements are suggested.

2. Roles of turbulent diffusion and horizontal turbulent transfer of mechanical energy (ε_π) in cyclone dynamics, especially at a final stage of development are estimated.

3. Mathematical models of dynamics of vertical movements of the saturated and damp non-saturated cloudy atmosphere are obtained. The numerical scheme of changes of pressure is suggested. Vertical speeds are described and model and method of the vertical movement calculation in the multilayered cloudy atmosphere taking into account frontal surfaces. Examples of numerical calculation of vertical movements near clouds are given.

4. Numerical models of the atmosphere dynamics are developed, the main models of atmospheric circulation and numerical finite-difference scheme of baroclinic processes of the atmosphere and also for the short-term forecast the baroclinic processes of the atmosphere are obtained, and the mathematical model of stationary atmospheric processes is suggested.

5. Mathematical models of transfer and dispersion of harmful substances in the real atmosphere at changeable profile of speed are obtained.

For research of the local atmospheric processes taking place in the boundary layer, let us use the mathematical model based on system of equations of hydrothermodynamics. Due to rather small horizontal scales (50x50 km) of the considered mesometeorological processes, let us write the system of equations of hydrothermodynamics in Cartesian coordinate system *x, y, z*. As initial, the following equations is taken: motion, continuity, state, influxes of heat, specific humidity etc. Required functions, namely, velocity vector, temperature, potential temperature, pressure, density, specific humidity, tensor of viscous tension of flow, heat and moisture participate in these equations. They are functions of coordinate and time and obtained in the papers [3, 4] for real atmospheric processes.

The universal gas constant, latent heat of condensation, specific heat capacity of air in case of constant pressure, radiation component of heat influx, thermal equivalent of operation, free fall acceleration, Coriolis parameter participate in specific types of heat flow and moisture, tensor of viscous tension, condition of the environment. And speed of formation of liquid phase within the accuracy of turbulent members expressed via dry and moist adiabatic gradients.

One of important aspects in the solution of tasks of the atmosphere boundary layer is setting of mathematically correct and physically consistent initial and boundary conditions for system of equations of hydrothermodynamics [6]. Setting of initial and boundary conditions depends on features of each specific situation to a large extent. Therefore, let us consider some general comments: initial conditions at *t=0* in models of such type are set according to measurements and thus are among input parameters. However, in practice it is difficult to obtain detailed physical information on initial mesoscale fields. Therefore, for carrying out numerical calculations for this type of atmospheric circulation, let us consider an initial field of perturbations as zero. In this case, the solution of task in case of small values of time will describe adaptation of meteorological fields to conditions when turbulence takes place in the process. Let us consider the system of equations of hydrothermodynamics:

- motion

$$\frac{du}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + lv + \frac{\partial \tau_{11}}{\partial x} + \frac{\partial \tau_{12}}{\partial y} + \frac{\partial \tau_{13}}{\partial z}; \quad (1)$$

$$\frac{dv}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - lu + \frac{\partial \tau_{21}}{\partial x} + \frac{\partial \tau_{22}}{\partial y} + \frac{\partial \tau_{23}}{\partial z}; \quad (2)$$

$$\frac{dw}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial z} - g + \frac{\partial \tau_{31}}{\partial x} + \frac{\partial \tau_{32}}{\partial y} + \frac{\partial \tau_{33}}{\partial z}; \quad (3)$$

- continuity $\frac{\partial p}{\partial t} + div \rho \vec{u} = 0$; (4)

- state (Clapeyron) $p = \rho RT$; (5)

- heat influx

$$\frac{d\theta}{dt} = \frac{L_w}{c_p}F + Q_H + \frac{\partial H_1}{\partial x} + \frac{\partial H_2}{\partial y} + \frac{\partial H_3}{\partial z}; \quad (6)$$

specific humidity:

$$\frac{dq}{dt} = -F + \frac{\partial Q_1}{\partial x} + \frac{\partial Q_2}{\partial y} + \frac{\partial Q_3}{\partial z}; \quad (7)$$

$$\theta = T\left(\frac{1000}{p}\right)^{\frac{AR}{c_p}}, \quad (8)$$

where

$$\frac{d\varphi}{dt} = \frac{\partial \varphi}{\partial t} + u\frac{\partial \varphi}{\partial x} + v\frac{\partial \varphi}{\partial y} + w\frac{\partial \varphi}{\partial z} \equiv \frac{\partial \varphi}{\partial t} + \vec{U} grad \varphi,$$

$$\varphi = (u, v, w, \theta, q).$$

The speed of formation of liquid phase F within the accuracy of turbulent members is presented in the form of [2].

$$F = i\frac{c_p}{L_w}(\gamma_a - \gamma_b)W; \quad i = \begin{cases} 1 & q \ge q_n \\ 0 & q < q_n \end{cases}, \quad (9)$$

where γ_a – dry adiabatic gradient; γ_a, γ_b – moist adiabatic gradient determined by formula:

$$\gamma_b(P,T) = \gamma_a \frac{p + 0{,}622\frac{L_w E}{RT}}{p + 0{,}622\frac{L_w^2 E}{c_p R_n T^2}}, \quad (10)$$

where t – time; u, v, w – wind velocity vector components in the directions of Cartesian coordinates x, y, z respectively; T – temperature; θ – potential temperature; p – pressure; q – specific humidity; ρ – density; R – universal gas constant; L_w – latent heat of condensation; c_p – specific heat capacity of air in case of constant pressure; Q_H – radiation component of heat influx; A – thermal equivalent of operation; g – gravitational acceleration; l – Coriolis parameter; $\tau_{i,j}$, $(i = \overline{1,3},\ j = \overline{1,3})$ – Reynolds viscous stress tensor; H_i, Q_i, $i = \overline{1,3}$ – heat and moisture flows in directions x, y, z respectively.

Type of items $\tau_{i,j}$, H_i, Q_i is concretized separately.

Let us consider the system of equations (1-10) under the following initial and boundary conditions:

$$u' = 0,\ v' = 0,\ \theta' = 0,\ q' = 0, \quad H(x,y) = H^0(x,y) \text{ at } t=0; \quad (11)$$

$$\frac{\partial u'}{\partial x} = 0,\ \frac{\partial v'}{\partial x} = 0,\ \frac{\partial \theta'}{\partial x} = 0,\ \frac{\partial q'}{\partial x} = 0 \quad (12)$$

at $x = \pm X$;

$$\frac{\partial u'}{\partial y} = 0,\ \frac{\partial v'}{\partial y} = 0,\ \frac{\partial \theta'}{\partial y} = 0,\ \frac{\partial q'}{\partial y} = 0 \quad (13)$$

at $y = \pm Y$;

$$u' = 0,\ v' = 0,\ \theta' = \alpha \Delta T,\ q' = 0,\ \pi' = 0, \quad w' = \frac{dH}{dt} \text{ at } z = H(x,y,t); \quad (15)$$

$$u = 0,\ v = 0,\ \theta' = f(x,y,t),\ w = \frac{d\delta(x,y)}{dt}, \quad q' = \tilde{Q}(x,y,t) \text{ at } z = \delta(x,y), \quad (16)$$

where $\Delta T = T_{heat} - T_{cool}$, $H^0(x,y)$ – initial specified height of layer of inverse.

Functions *f*, $\widetilde{Q}$ are supposed to be specified.

In this case, there will appear the task of atmosphere boundary layer in case of motion of air mass over thermally and orographically non-uniform surface with the free upper boundary of air mass, which is considered under the boundary conditions. Creation of geoecological map of impurity transfer using atmosphere boundary layer model with nonstationary upper bound of air mass. In the atmosphere, inversion situations when warmer air mass is above cold one are often observed. These air masses are separated by free surface *H (x, y, t)* which is required value. At the same time, it is possible to assume that height of atmosphere boundary layer coincides with lower boundary of inverse.

Unlike boundary layer problem statement where upper boundary usually has the fixed height, in this case, function *H (x, y, t)* is one of required characteristics. Therefore, use of such model requires conversion of equations system of hydrothermodynamics so that to determine function *H (x, y, t)* during the solution of task along with other meteoelements, and at the same time, to consider structure of relief of spreading surface.

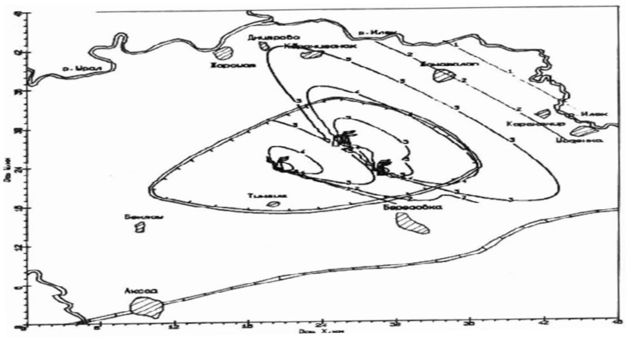

Figure 1. Isolines of distribution of CO_2 concentration at the height of 100 m

Calculations were also carried out for the most abnormal weather conditions, i.e. when the convection contributing to dispersion of impurity or the significant inverse, in case of which accumulation of harmful substances can happen exceeding admissible concentration limit (ACL), predominate in the atmosphere. In all carried-out calculations, it was supposed that impurity is single-component and passive.

Effective height of sources was equal to 50 m on average. At the same time, height is understood as the sum of pipe geometrical height *N* and additional height. The letter is defined by rise of impurity cloud over a pipe cutoff, which is caused by existence of original number of motion in the stream of gases from pipes and their overheating in relation to atmospheric air. Besides, calculations were presented for two emission components that is nitrogen dioxide (NO_2) and sulphurous gas (Q_0), at the same time, their deposition rate was determined by Stokes formula. The background weather conditions are selected proceeding from data of aerological station and urgent observations. Background stratification of the atmosphere was determined by average daily temperature gradient vertically to the level of 850 Mb. Now, let us consider one variant of the executed calculations carried out in accordance with hydrodynamic model of dispersion of impurity in surface boundary layer near Karachaganak oil and gas extraction field. Thus, the area of 48 m^2 was selected so that sources were arranged approximately in the middle, and in subsequent, this region was covered with a grid of step of 2000 m. Thus, calculations were executed in a grid 24*24*18. In all cases, the operation mode of sources was supposed stationary, i.e. $Q(t)=Q_0$=const. Integration step of time is Δt=10 min. Different amount of time was expended for different variants of computation.

Example. In this case, the result of numerical modeling of dispersion of sulphurous gas under the conditions of winter is considered. Background characteristics for model are borrowed from results of real observations. As a background flux let us consider wind at the level of 850 Mb with value U_q=5.1 m/s; V_q=3.1 m/s. In the Figure 2, isolines of distribution of concentration of sulphurous gas (SO_2) at the level of Z=2m at time point of *t*=16 hours are presented. From this, it follows that concentration is generally localized in neighborhood of sources. But in this case, the zone exceeding admissible concentration limit is almost not observed. The greatest value corresponding to isoline with number 7 is 0.0071 mg/m^3.

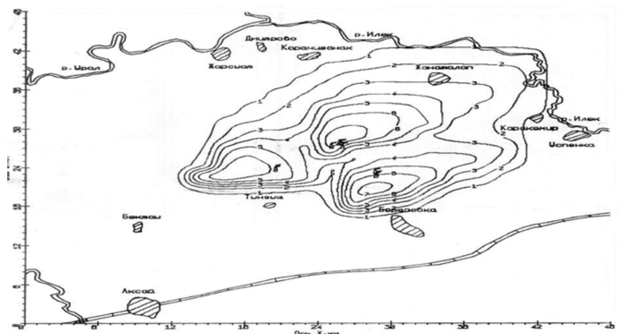

Figure 2. Isolines of concentration of sulphurous gas at the level of Z=2 m at time point *t*=16 hours

Let us consider concentration of isolines at the level of source. In this case, accumulation of concentration NO_2 takes place in the plane z=50 m, where zones in which impurity exceeds admissible concentration limit by several dozens are observed. This case is typical for high-altitude sources when in a ground layer steady inverse of temperature takes place due to radiation cooling. In this variant, the following cha- racteristics of meteoelements at soil temperature -27 ^{0}C, air temperature-18 ^{0}C and -12 ^{0}C at the levels *z*=2 m and *z*=50 m respectively were calculated by the model. From here, it is possible to draw a conclusion that in case of intensive inversion situations, formation of zone with the increased maintenance of concentration is improbable in ground layer of the atmosphere. Zones, where exceeding of admissible concentration limit takes place, are expected at the level of effective height of sources.

Thus, developed mathematical models and programs complex describe the real processes taking place in the real atmosphere and calculate a level of pollution of atmospheric air of the industrial region. Factors affecting the air pollutions are revealed, mathematical models methods, diagrams of computing circuits are determined; it is seen that suggested mathematical apparatus allows development of complex of actions for reduction of level of environmental pollution. The developed program complex will make it possible to carry out monitoring of oil and gas extraction field, to control functioning of ecological systems, and also to prevent economic damage during ecological pollution and their elimination.

Geoecological maps of harmful impurity transfer under convective conditions

Figures 3-4 are devoted to distribution of impurity of types SO_2 and NO_2 under convective atmospheric conditions. In these Figures, isolines of concentration SO_2 and NO_2 are presented (in shares of admissible concentration limit exceeding) at three levels on height for the time point corresponding to complete blowing of the deposit area. This time is approximately equal to 40000/u_r sec, where u_r – the surface speed of air in advance for this option of calculation. And it usually corresponds to a time frame when distribution of impurity acquires steadiness. In a series of calculations (Figures 5, 6), wind speed is doubled in comparison with option of calculation provided in Figures 3, 4. It is seen that increase in wind speed is conductive to more intensive removal of impurity from the deposit area. as it was already mentioned, the most intensive source of pollution is the aggregate UKSP-16. Moreover, these sources have also the greatest effective height of emissions under the considered conditions about 60 m. Therefore, as Figures 5 and 6 show, the greatest exceeding of admissible concentration limit takes place at this height. As for NO_2, several times exceeding of admissible concentration limit is observed at all heights including ground layer. It is due to large volume of emission of this impurity from the aggregates UKSP-16. The exceeding of emissions volume of NO_2 in comparison with SO_2 is about 500. Partisipation of remaining sources of pollution in total pollution is not so considerable; and besides, their effective height is rather small (50-100 meters). Distribution of NO_2 in Figure 4 is of great interest.

Impurity is spread in the direction of air mass moving, and as velocity vector to the left can be turned within an atmosphere boundary layer, the form of dispersion at various heights has similar orientation. For example, it is seen from the analysis in Figure 4.

Geoecological maps of harmful impurity transmission under inversion conditions

Distribution of impurity under steady atmospheric conditions was carried out for two variants: in the first case, wind speed in ground layer is selected equal to 2 m/s (Figure 7), and in the second case, it is 4 m/s (Figure 8). Time of calculation corresponded to the period of complete blowing of deposit area with length about 40 km. Increase in wind speed leads to stimulation of more intensive spreading of pollution out of this region. Effective height of emissions is maximum for aggregates UKSP-16 (70-100 m), and for other sources of pollution it is near upper boundary of ground layer (10-20 m). As the most powerful sources have rather big effective height, the maximum precipitation of impurities in a ground layer is observed far from sources because of inversion conditions (Figure 8).

Distribution of impurity takes place in the direction of wind; at that, under convective conditions, change of this direction is noticeable from height (left swing according to the Ekman model). More intensive pollution by impurity of NO_2 at height close to the effective height of emission should be noted. For example, exceeding of admissible concentration limit in Figure 6 is several hundreds. It is explained by the fact that under inversion conditions, there are no upward flows of air and vertical turbulence is poorly expressed; it leads to localization of emissions near pollution sources. The effect when increase of wind leads to more intensive pollution close to earth and at the fixed height about 70 m is observed in course of the analysis of calculations for the elementary model under steady conditions. It is linked with the similar fact, that is increase in wind speed in case of invariable meteoparameters reduces noticeably the effective height of emissions. And in turn, it leads to approximation of height of smoke jet axis to the Earth surface. Thus, it is possible to draw a conclusion that along with the known dangerous weather conditions, which are formed in case of inverses and their combinations with no-wind conditions, the indicated weather conditions are also among the most dangerous.

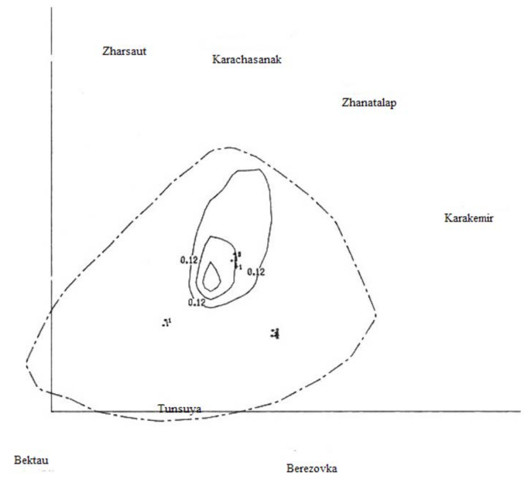

Figure 3. Isolines of CO_2 concentration in admissible concentration limit shares at the height of 250 m.
Max CO_2 – 0.47

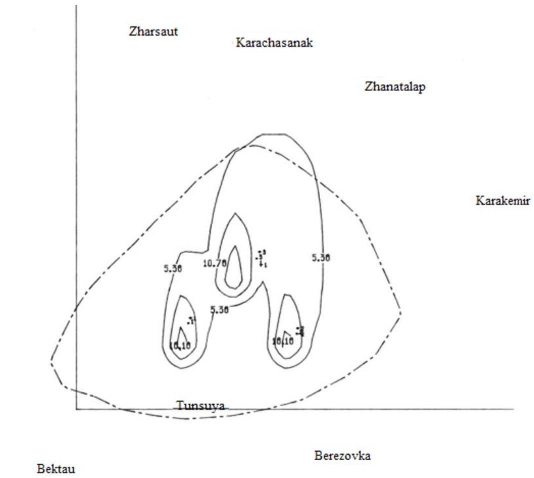

Figure 4. Isolines of NO_2 concentration in admissible concentration limit shares at the height of 650 m.
Max NO_2 – 0.47

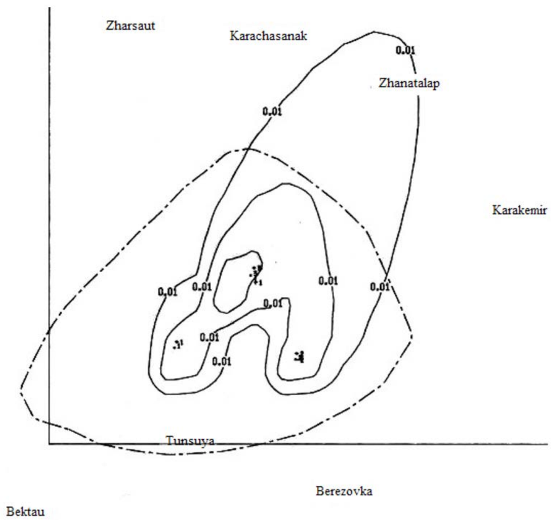

Figure 5. Isolines of CO_2 concentration in admissible concentration limit shares at the height of 50 m.
Max CO_2 – 0,03

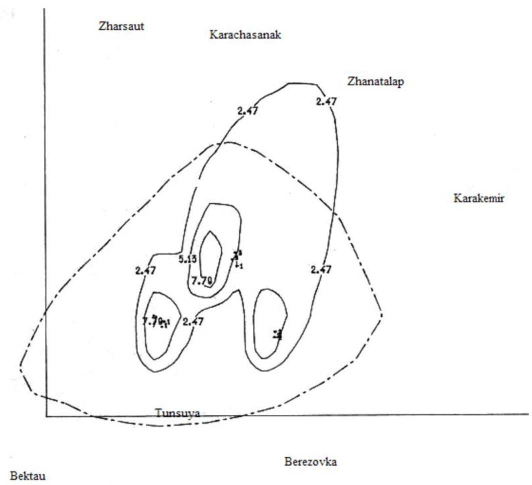

Figure 6. Isolines of NO_2 concentration in admissible concentration limit shares at the height of 650 m.
Max NO_2 – 10,44

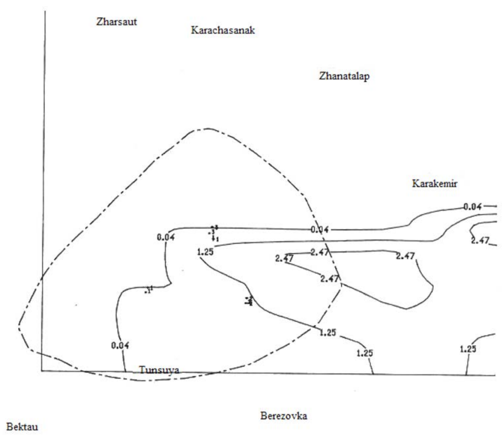

Figure 7. Isolines of CO_2 concentration in admissible concentration limit shares at the height of 10 m.
Max CO_2 – 3.69

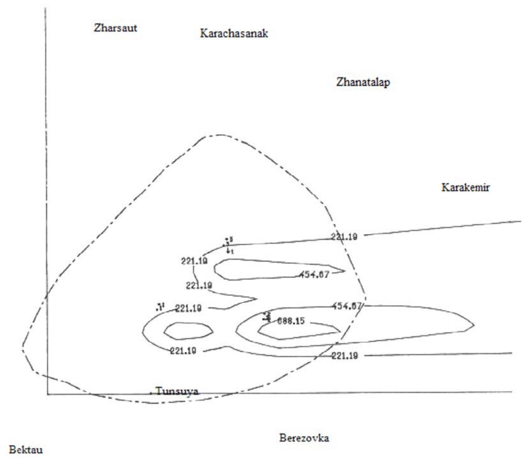

Figure 8. Isolines of NO_2 concentration in admissible concentration limit shares at the height of 70 m.
Max NO_2 – 921.63

Conclusions

The conducted researches on determination of level of impact of production processes of oil and gas industry on environment of the West Kazakhstan will allow determination of necessary measures for its protection. The complex of measures for protection of the air atmosphere is developed and suggested, nature protection measures and approaches to support of ecological safety are developed, namely, complex of actions for reduction of emissions in the atmosphere, actions for protection of waters and soil cover, and also economic efficiency from implementation of nature protection measures is determined, the analysis of actions for reduction of harmful substances emissions during the transportation and storage of oil products is carried out.

On the basis of suggested complex of models and program products, it is possible to solve the following practical and research tasks on study of local circulation within the limited area:

- study of influence of anthropogenous changes of properties (thermal, dynamic, humidity, etc.) of layering surface on dynamics of the atmosphere boundary layer;

- study of regularities of polluting impurity spreading together with development of hydrothermodynamic processes under different weather conditions (inverse, no-wind condition, external flow, etc.) considering changes of characteristics of area layering surface;

- numerical modeling of the hydrometeorological mode of the area, assessment and monitoring of pollution of atmosphere and industrial regions.

The model of local atmospheric processes with free upper boundary was adapted for simulation of atmospheric circulation of the region. It is a complex of mathematical models which connection to conditions of the certain region is carried out at the level of input information.

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