CHANGES IN THE CONCENTRATION OF POLLUTANTS IN THE ATMOSPHERE OF THE REGION UNDER THE INFLUENCE OF ATMOSPHERIC CONDITIONS

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Abstract: *this article describes the effect of atmospheric conditions on the behavior of the concentration of harmful substances in the atmosphere. A new approach to calculating the concentration of harmful emissions from a point source is considered, taking into account the peculiarities of the state of the atmosphere for the city of Ust-Kamenogorsk. In particular, a method for calculating the dispersion coefficients for the city of Ust-Kamenogorsk based on the "Gifford-Pasqual" nomograms for all categories of atmospheric stability is proposed. The characteristics of turbulent transport are described, along with the scales of the transport of impurities. The dispersion parameters were calculated for the city of Ust-Kamenogorsk.*
Keywords: *atmospheric pollution, concentration of harmful substances, impurity transfer, atmospheric categories of stability, dispersion parameters.*

ИЗМЕНЕНИЯ КОНЦЕНТРАЦИИ ЗАГРЯЗНЯЮЩИХ ВЕЩЕСТВ В АТМОСФЕРЕ РЕГИОНА ПОД ВЛИЯНИЕМ АТМОСФЕРНЫХ УСЛОВИЙ

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Аннотация: *в данной статье описывается влияние атмосферных условий на поведение концентрации вредных веществ в атмосфере. Рассмотрен новый подход к расчёту концентрации вредных выбросов от точечного источника, учитывающий особенности состояния атмосферы для г. Усть-Каменогорска. В частности, предложена методика вычисления коэффициентов дисперсии для г. Усть-Каменогорска на основе номограмм "Гиффорда-Паскуилла" по всем категориям стабильности атмосферы. Описаны характеристики турбулентного переноса, масштабами переноса примеси. Произведен расчёт дисперсионных параметров для города Усть-Каменогорска.*
Ключевые слова: *атмосферное загрязнение, концентрация вредных веществ, перенос примеси, категории устойчивости атмосферы, дисперсионные параметры.*

At present, all over the world, great importance is attached to improving the environmental situation in industrial cities. In this regard, calculations showing the level of environmental pollution from an industrial enterprise are relevant and allow you to assess the damage arising from emissions of harmful substances. To carry out such calculations, it is necessary to take into account the geographical position of the settlement, the features of the earth's surface near the settlement, as well as the category of atmospheric stability.

The solution of the problem of finding the concentration of harmful substances from a point source of emissions requires finding the dispersion coefficients for a certain settlement, in our case for the city of Ust-Kamenogorsk, where there is a large concentration of industrial enterprises [1].

This article discusses a new approach to calculating the concentration of harmful emissions from a point source, taking into account the peculiarities of the state of the atmosphere for Ust-Kamenogorsk. In particular, a method for calculating the dispersion coefficients for the city of Ust-Kamenogorsk based on the "Gifford-Paskuill" nomograms for all categories of atmospheric stability is proposed. This approach makes it possible to better calculate the concentration of harmful substances from the emissions of an industrial enterprise [2].

In the theory of modern gas dynamics, there is a complex problem of calculating the turbulent transport of impurities and their dispersion in the atmosphere. The main works [1] in which an attempt was made to calculate give a general approach to the calculation method for a particular region.

When a toxicant is released, the size of the toxic hazard zone depends both on the emission power and on the characteristics of atmospheric transfer, namely, on the wind speed and on the category (class) of stability (stability) of the atmosphere. Basically, the categories differ in the intensity of vertical air mixing.

In the literature there is no generally accepted criterion for determining the categories of stability, however, most researchers use the simplest classification (Pasquilla) according to the vertical temperature gradient [3]. Since the state of stability of the atmosphere is essentially determined by the intensity of vertical convective currents, it can change significantly during the day. The typical distribution of atmospheric stability during the day for middle latitudes is shown in Figure 1. As can be seen, the distribution of atmospheric stability states in the cold and warm seasons is very different. So, in the cold season, neutral and stable conditions of the atmosphere dominate, and in the warm season: at night - stable, and during the day - unstable.

For powerful vertical high-speed emissions or high-temperature emissions, as well as in cases where the emission source is located at a considerable height from the earth's surface, it is very important to take into account the dependence of the mixing layer (the surface layer of the atmosphere with an approximately constant shear stress) on the state of the atmosphere. According to foreign researchers, the height of the mixing layer on average varies from 100m at night to 2000m in the daytime [3]. In this case, the maximum value of the height of the mixing layer is reached 3-4 hours after sunrise.

To describe the dependence of the realization of one or another class of atmospheric stability on the wind speed “U”, we analyzed the data of observation stations in the USA [4-5] and in the Russian Federation [6].

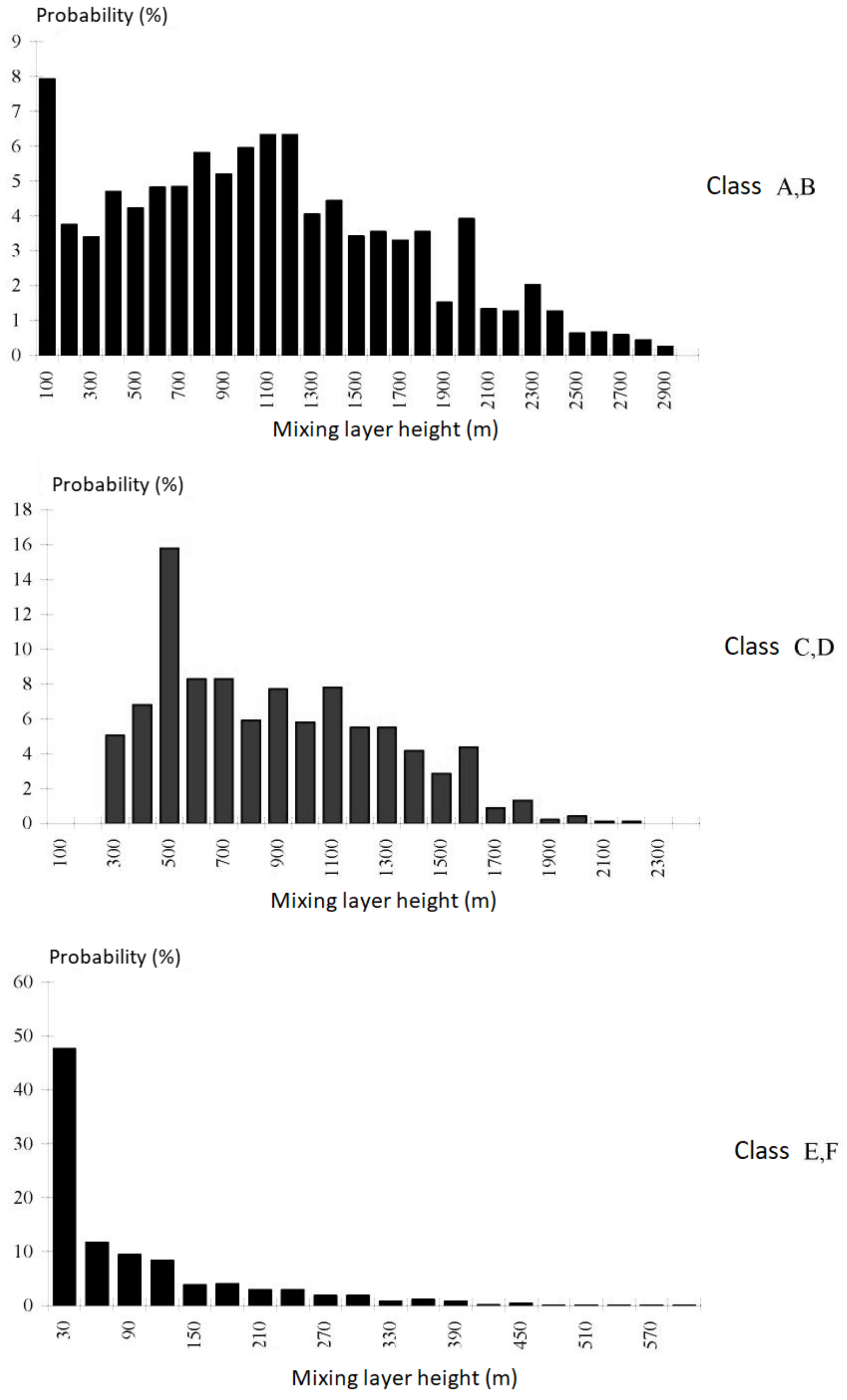

Fig. 1. Frequency distribution of different heights of the mixing layer for different atmospheric conditions

It is known that wind speed varies significantly with altitude. In applied research, the power-law dependence of the form is most often used:

$$U(z)=U_0(z/z_0)^p, \qquad (1)$$

where U_0 is the wind speed at the “standard” height z_0 (usually $z_0 = 10\ m$), the values of the *"p"* index also depend on the class of stability of the atmosphere and the "roughness" of the surface Δ_0.

From [6], the distribution of impurity concentration on the axis of the track $(y = 0)$ on the earth's surface $(z = 0)$ from a point source of constant power G_0. equally:

$$C(x,0,0) \approx \frac{G_0}{2\pi \cdot U \cdot \sigma_y(x) \cdot \sigma_z(x)} \qquad (2)$$

Typically, the dispersion coefficients in the horizontal and vertical directions σ_y and σ_z are calculated using empirical relationships. The most famous nomograms of *"Gifford-Pasquill"* [6], compiled from the observations of concentration in the flat area and therefore called *"rural"*.

Briggs made similar observations in urban areas, and therefore his coefficients are sometimes called "urban". For an unstable atmosphere, the ay coefficients are higher than the rural ones up to about 5 km, but then they decrease significantly [6]. The approximation coefficients a_i, b_i and c_i were calculated for the city of Ust-Kamenogorsk (Table 1).

Table 1. Formula constants

Constants	**Atmospheric stability category**					
	A	B	C	D	E	F
a_y	-1,104	-1,634	-2,054	-2,555	-2,754	-3,143
b_y	0,9878	1,0350	1,0231	1,0423	1,0106	1,0148
c_y	-0,0076	-0,0096	-0,0076	-0,0087	-0,0064	-0,0070
a_z	4,679	-1,999	-2,341	-3,186	-3,783	-4,490
b_z	-1,7172	0,8752	0,9477	1,1737	1,3010	1,4024
c_z	0,2770	0,0136	-0,0020	-0,03116	-0,0450	-0,0540

Today in the literature [1] there is extensive information on the construction of both complex (three-dimensional) and simpler transfer models based on empirical data.

To predict the distribution of toxicant concentrations around the source, we use the Gaussian model of turbulent diffusion. The mathematical expression for the concentration of a substance from a point source with a constant power - Q_**(kg/s)* is written in the following form:

$$C(x,y,z,t) = \frac{f(A)\cdot Q_*}{2\pi\sigma_y\sigma_z U}\cdot \exp(-\frac{y^2}{2\sigma_y^2})\cdot[\exp(-\frac{(z-H)^2}{2\sigma_z^2}) + \exp(-\frac{(z+H^2)}{2\sigma_z^2})], \qquad (3)$$

where Q_* is the power of the source *(kg/s)*; σ_y and σ_z – dispersion parameters depending on the stability of the atmosphere and the distance from the source *"x" (m)*, *U* – wind speed *(m/s)*; *H* – source height *(m)*; *x, y, z* – axial, transverse and vertical coordinates; *f(A)* – the proportion of impurities in the mixing layer (*"A"* - the height of the mixing layer).

This dependence in relation to real conditions of emission with a concentration of C_0 is corrected by the introduction of the concept of a virtual source. In this case, x_0 is calculated so that at the point *(x=0, y=0, z=H)*, the equality is observed:

$$C_0 = \frac{f(A)\cdot Q_*}{2\pi\cdot\sigma_y(x_0)\sigma_z(x_0)\cdot U} \qquad (4)$$

In further calculations, the dispersion parameters are corrected taking into account the x_0 value, i.e. $\sigma_y=\sigma_y(x+x_0)$; $\sigma_z=\sigma_z(x+x_0)$. As a rule, $f(A)=1$ is taken for relatively small values of heights ($H < 100\text{-}200$ *m*) [6].

Figure 2 shows the results of modeling the process of concentration distribution by coordinates from a single source. The data were obtained by formula 4 with the substitution of the approximation coefficients a_i, b_i and c_i calculated by us to calculate the variance parameters (table 1).

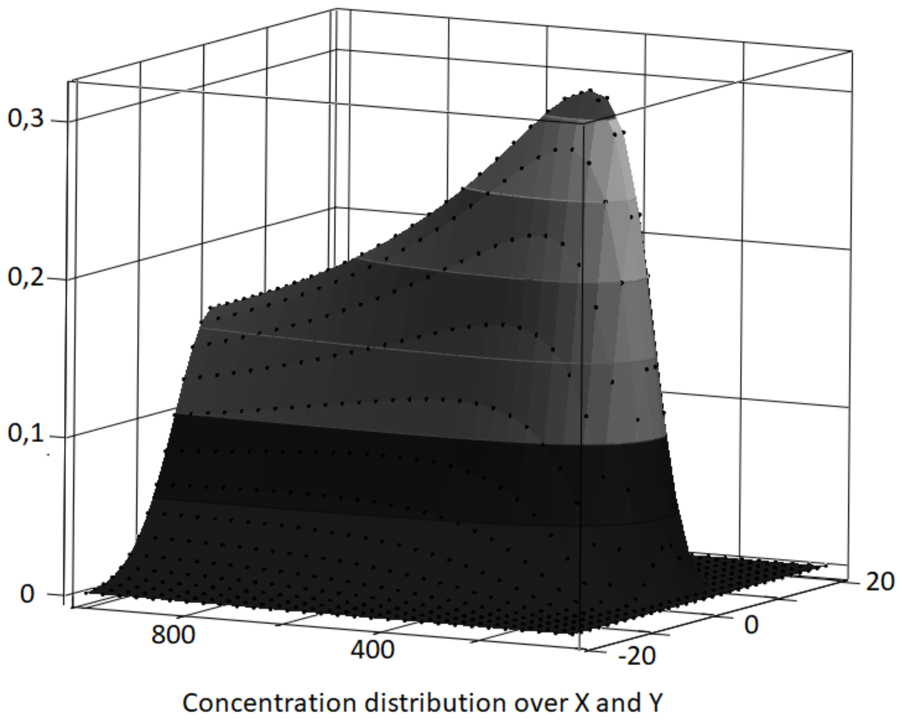

Fig. 2. Distribution of concentration along the X-axis in the range from 10 meters to 1000 meters, along the Y-axis from -20 to 20 meters

The concentration of pollutants displayed on the 3D graph changes according to the color – from black to dark gray. It can be seen (Figure 2) that in the direction of the wind with a speed of *U=1 m/s*. (coinciding with the *X*-axis), with a pipe height *H=50 m* at a distance of 1000 m, it decreases by 45%. The color change step is 3%, the whole range is 30 colors. This allows you to visually understand the function of changing the concentration and highlight the area of the highest concentration of harmful substances, in this case it is an area of light gray hue.

Figure 3 shows a picture of the real distribution of the plume from the real source, photographed in May 2020. The dots mark the calculation results (Figure 2).

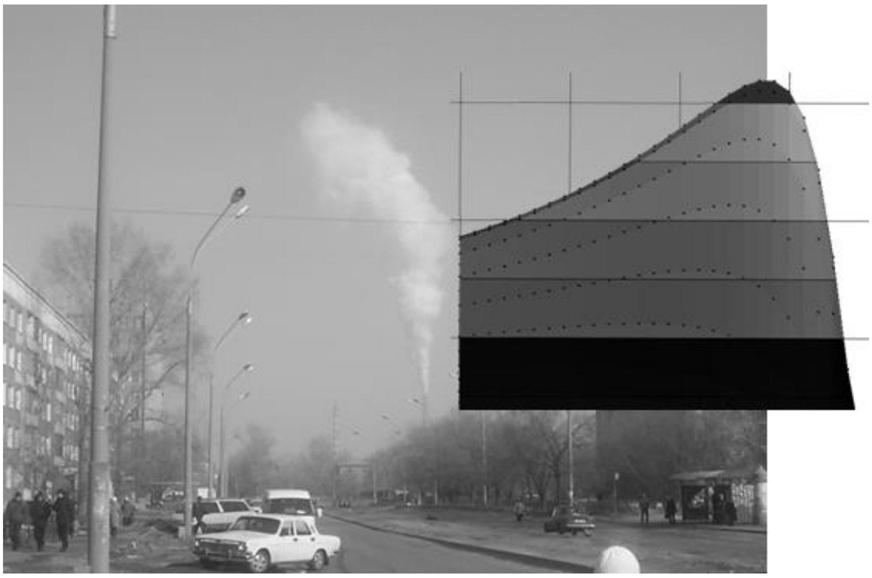

Fig. 3. Photo of the distribution of the plume from the real source with the overlapping of calculated values

It can be seen that the calculated data are in good agreement with the actual behavior of emissions from this source. Such a coincidence of the calculated and practical data indicates the correct calculation of the dispersion parameters for the city of Ust-Kamenogorsk.

The calculations of the dispersion coefficients carried out in the work made it possible to calculate the concentration of harmful substances arising from the emissions of an industrial enterprise. In the future, the dispersion coefficients can be used to calculate the accumulated average annual accumulated concentration of various harmful substances in Ust-Kamenogorsk, as well as calculate the risks of danger to human life and determine the impact of the environmental situation in Ust-Kamenogorsk on public health.

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