PARAMETERIZATION OF THE TURBULENT DIFFUSION COEFFICIENT OF INDUSTRIAL EMISSIONS

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Annotation

Turbulent diffusion of industrial emissions is one of the main transport mechanisms that determine the spatial distribution of pollutants in the atmospheric boundary layer. One of the famous ways to study the basic laws of the spatial distribution of the contaminant is a mathematical modeling of the transport of particles in the air. A diffusive-convective transport model had got wide recognition. A parameter of the diffusive-convective transport model is a vertical eddy diffusion coefficient k_z. In the simulation of vertical transport impurities the parameterization of turbulent diffusion coefficient is often used in the form: $k_z = k_{pr} * z$. A parameter k_{pr} essentially depends on roughness and temperature heterogeneity of the underlying surface, convective flow and disperse composition impurities. Due to the complexity of the turbulence diffusion processes, adequate description of the vertical transporting is not possible without the involvement of the models, based on experimental materials. In this paper we propose the parameter describing the turbulent diffusion of industrial emissions determinate like solving an inverse problem on the distribution of the contaminant measured along a certain direction from a point source. The content of harmful substances in the air is relatively small, especially at a considerable distance from the source. Therefore, to measure the distribution of the contaminant it is advisable to use the method of moss-biomonitors, exposure time of which is determined by the length growth of moss and it is a year or more. The method is widely used to study air pollution by heavy metals (HM) [1-4].

Modeling of spatial distribution of contaminant concentrations in the surface layer of the atmosphere

Modeling of the spatial distribution of HM, containing in industrial emissions, is based on the diffusion-convection transport equation, which has the form [5]:

$$u\frac{\partial q}{\partial x} + V_g\frac{\partial q}{\partial z} = \frac{\partial}{\partial z}k_z\frac{\partial q}{\partial z},$$

for the average values of impurity concentrations q excluding turbulent diffusion in the horizontal plane of the surface atmosphere. Where u - wind speed in the x-direction; V_g - gravitational settling velocity of impurity particles.

An analytical solution of this equation as a power approximation of the wind speed and the vertical turbulent diffusion coefficient for a point source, taking into account background concentrations q_f, is taken the following form [5,6]:

$$q(x) = \theta_1 x^{\theta 2} exp\left(-\frac{\theta_3}{x}\right) + q_\phi$$

In accordance with previous work [5] the distribution parameter θ_3 can be written as follows:

$$\theta_3 = \frac{u_1 H^{1+n}}{(1+n)^2 k_{np}}$$

where n - is a parameter characterizing the change in wind speed with height, H -is a height of the pollution source pipe; u_1-is a wind speed at a height of 1 m.

Numerical value of θ_3 parameter can be found using the method of least squares (MLS) by function of the form (2) for the approximation of the measured distribution. Then the expression (3) can be used to determine k_{pr} by substituting wind speed value averaged in the selected direction during the exposure time.

Experiment

The study used a three-year growth of epiphytic moss Pylaisia polyantha (Hedw.) BSG, which were taken in the area of influence of CHP-5 in Novosibirsk (Russia). Sampling was carried out in a northeasterly direction from the CHP-5 from the bark of birch and poplar trees at a height of 1.5-2 meters from the ground at distances from one to five kilometers. Background samples were taken on a site remote from the main population centers and businesses over a distance of 200 km. Background samples were taken on a site remote from the main population centers and businesses over a distance of 200 km.

Determination of chemical elements in the moss samples was produced by neutron activation method at the research reactor IRT-T of National Research Tomsk Polytechnic University (Russia). In the study, 38 samples of moss were prepared and measured, which determined the content of the following elements: Ba, Hf, Eu, Fe, Yb, Co, La, Lu, As, Nd, Rb, Sm, Sc, Sr, Sb, Cr, Cs , Ce, Zn; sample preparation was performed according to procedure [4]. As an example, Pic.1 shows the concentration distribution of Co and Sr given the level of background, the solid line shows the results of the approximation of the measured values by the function (2) by MLS.
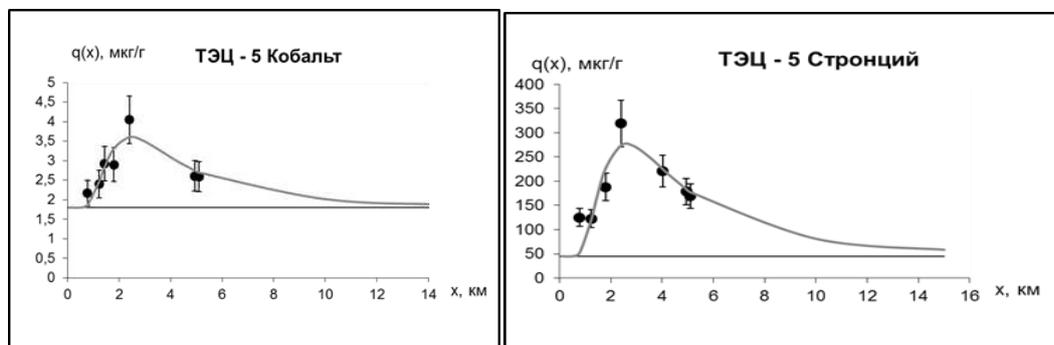
Pic.1 Distribution of Co and Sr concentrations depending on the distance: solid curve – is the result of the approximation function (2), the horizontal line – is background concentrations.

Table 1 shows k_{pr} and vertical eddy diffusivity k_z on different heights with n = 0,2 and the average wind speed u1 = 3,7 m / s, the values of the parameter θ_3, defined by OLS.

Table 1 The value of parameters θ_3, k_{pr} and vertical diffusion coefficient k_z at different heights (n = 0,2; u1 = 3,7 m / sec.)

Element	θ_3	$k_{пр}$, m/s	$k_{zэф}$, m^2/s			
			z=100 m	z=150 m	z=200 m	z=250 m
Ba	8	0,08	7,6	11,5	15,3	19,1
Hf	6	0,1	10,4	15,6	20,8	26
Eu	5	0,12	12,3	18,4	24,5	30,6
Fe	10	0,06	5,9	8,8	11,8	14,7
Yb	8	0,08	7,6	11,5	15,3	19,1
Co	8	0,08	7,6	11,5	15,3	19,1
La	8	0,08	7,6	11,5	15,3	19,1
Lu	8	0,08	7,6	11,5	15,3	19,1
As	8	0,08	7,6	11,5	15,3	19,1
Nd	8	0,08	7,7	11,5	15,3	19,1
Rb	7	0,09	9,3	14	18,6	23,3
Sm	8	0,08	7,7	11,5	15,3	19,1
Sc	9	0,07	6,6	9,9	13,3	16,6
Sr	8	0,08	7,7	11,5	15,3	19,1
Sb	8	0,08	7,7	11,5	15,3	19,1
Cr	8	0,08	7,7	11,5	15,3	19,1
Cs	8	0,08	7,7	11,5	15,3	19,1
Ce	7	0,09	9,4	14,1	18,8	23,6
Zn	8	0,08	7,7	11,5	15,3	19,1

The values of K_{pr} parameter are in the range of 0.07 ... 0.12 m / s, the average value at significance level of 0.05 and confidence interval ± 0,003 m / s for this sample is k_{pr} = 0.082 m / s. It was found by the distributions of 19 chemical elements. The k_{pr} parameter is the result of averaging over all states of the atmosphere at a particular location during the exposure time (in our case over 3 years). According to [5] for the convective transport model k_{pr} is in the range 0.1 ... 0.2 m / s, and at a temperature inversion the k_{pr} coefficient is significantly lower. Comparison of these data with the results obtained in the study shows that in the area adjacent to the CHP-5 Novosibirsk, a convective conditions of transfer are more likely.

Found via moss biomonitoring values of vertical turbulent diffusion coefficient can be used during the annual estimates of levels of contamination of the surface layer of the atmosphere by HM. Also it can be used to predict the spatial distribution of the contaminant in the atmospheric boundary layer for the sources of pollution that located on the study area. Modeling the spatial distribution of the contaminant using the parameter values kpr also allows determining the zone of influence of factories and deposition of HM region.

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