# PARAMETERIZATION OF THE TURBULENT DIFFUSION COEFFICIENT OF INDUSTRIAL EMISSIONS

E.A. Pokrovskaya, V.O. Babicheva

Scientific Supervisor: PhD Associate Professor N.K. Ryzhakova

Linguistic Advisor: Senior teacher N.V. Demjanenko

Tomsk Polytechnic University, 634050, Tomsk, Russia, Lenin Avenue, 30

E-mail: nkryzh@tpu.ru

**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 $\theta_3$ can be written as follows:

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

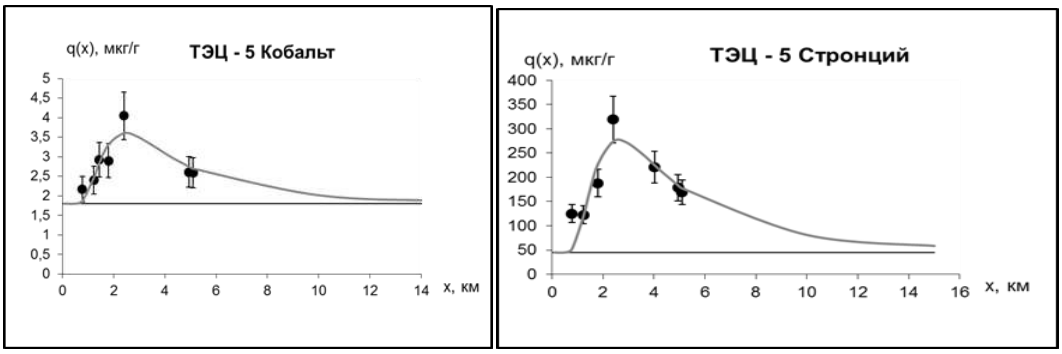
where n - is a parameter characterizing the change in wind speed with height, H -is a height of the pollution source pipe; $u_1$-is a wind speed at a height of 1 m.

Numerical value of $\theta_3$ 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 $\theta_3$, defined by OLS.

Table 1 The value of parameters $\theta_3$, $k_{pr}$ and vertical diffusion coefficient $k_z$ at different heights (n = 0,2; u1 = 3,7 m / sec.)

| Element | $\theta_3$ | $k_{пр}$, 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.

**References**

1. Harmens H., David N. and participants of the moss survey. (2008): Spatial and Temporal Trends in Heavy Metal Accumulation in Europe (1990-2005). Bangor. Wales. Programme Coordination Centre for the ICP

Vegetation. Centre for Ecology and Hydrology Centre for Ecology and Hydrology.

2. Coskun M., Cayir A., Coskun M., Kilic O. (2011): Heavy metal deposition in moss samples from east and south Marmara region, Turkey. Environmental Monitoring and Assessment, 174 (1-4): 219-227.

3. Shotbolt L., Büker P., Ashmore M. (2007): Reconstructing temporal trends in heavy metal deposition: Assessing the value of herbarium moss samples. Environmental Pollution, 147 (1-3): 120-130.

4. Рыжакова Н. К., Борисенко А. Л., Меркулов В. Г., Рогова Н. С. Контроль состояния атмосферы с помощью мхов-биоиндикаторов //Оптика атмос-феры и океана, 2009 – т. 22, – №1. с. 101 – 104.

5. Берлянд М.Е. Прогноз и регулирование загрязнения атмосферы. – Л.: Гидрометеоиздат, 1985. - 272 с.

6. Гусев Н. Г., Беляев В. А. Радиоактивные выбросы в биосфере: справочник - 2-е изд., перераб. и доп. - М.: Энергоатомиздат, 1991. - 256 с.

7. Н.К. Рыжакова, В.Ф. Рапута, Н.С. Рогова, А.Л. Борисенко, Е.А. Покровская. Пространственное распределение химических элементов атмосферных выбросов угольной ТЭЦ//Экология и промышленность России.- 2013-№. 1. – С. 52-55.