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On the Dispersed Composition of Ash and Slag Waste from Boiler-House

S A Chebanova¹, I V Polyakov², A B Strelyaeva¹

¹Volgograd State Technical University, Academicheskaya, 1, Volgograd, 400074, Russia

²EuroChem-VolgaKaliy, Lenina, 7, Kotelnikovo, 404354, Russia

E-mail: sveta_nes@mail.ru

Abstract. This work is devoted to the investigation of the dispersed composition of ash and slag wastes of municipal services. Based on the results of the studies, recommendations were developed to improve the methods for calculating the level of negative impact of urban services with storage and disposal yards for ash and slag wastes. The relevance of the study is connected with the assessment of the level of urban air pollution by emissions of fine dust. It has been experimentally proven that the storage and disposal yards for ash and slag wastes are sources of particulate emissions of different diameters, including fine particles less than 10 μm (PM_{10}) and less than 2.5 μm ($\text{PM}_{2.5}$). Recommendations have been developed to improve existing methods of calculation of emissions of solid particles with the subsequent calculation of concentration of fine dust. The results of the approximation are presented in the processing of experimental data on diffraction distribution of the mass of solid particles entering the atmospheric air from storage and disposal yards of ash and slag wastes.

1. Introduction

Combustion of solid fuel (coal) in boiler units, as well as during storage of coal in open warehouses and storage of ash and slag wastes, PM_{10} and $\text{PM}_{2.5}$ fine dust emissions are especially harmful to the urban environment. The level of atmospheric pollution by boiler plants burning coal as a fuel is estimated without taking into account the dispersed composition and aerodynamic characteristics of fine dust of ash. Specific emission standards of pollutants into the atmosphere are established for sulfur oxides, nitrogen oxides, carbon oxides, fly ash of solid fuel. At the same time, studies of the effect of fine dust ash dumps on air pollution are practically not carried out [1].

For rational urban planning solutions, studies of the level of atmospheric air pollution by finely dispersed particles of ash and slag wastes of urban facilities are relevant.

Many researchers have been and are engaged in the dissemination of polluting particulate matter in the atmosphere contained in the emissions. The results of investigations of many authors are laid in the basis of the theory of dust dispersion analysis [1-21].

The choice of research direction: investigation of the dispersed composition of fine particles of ash-and-slag wastes entering the atmospheric air from the ash dump; the choice of a mathematical apparatus and the processing on its basis of experimental data of dispersion analysis.



2. Investigation of the disperse composition of ash dumps dust

The authors carried out investigations of the dispersed composition of dust entering the atmospheric air with emissions from the ash dump of the boiler house according to the method of V.N. Azarov [9], using the HandHeld 3016 IAQ Combo and CEL 712 Microdust pro equipment. The dust was analyzed at four points: the ash ash dump (Figure 1), directly in the air of the ash dump (at a height of 1.5 m) (Figure 2), and at three points at a distance of 50 m from the ash dump: a vertical surface (1.5 m high) (Figure 3), a horizontal surface (at a height of 2.0 m) (Figure 4). The integral functions of the particle mass distribution over the diameters are constructed similarly to [1].

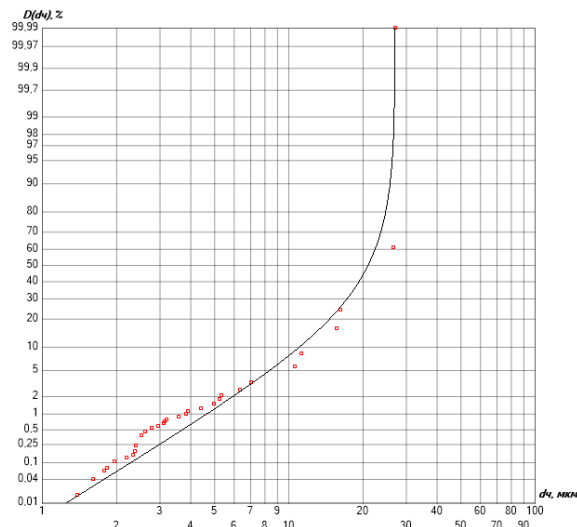


Figure 1. Integral distribution curves of particle mass $D(dp)$ over the dust diameters of the ash ash dump.

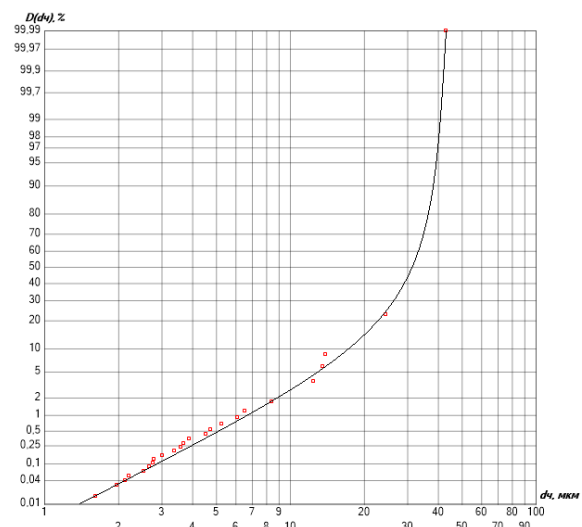


Figure 2. Integral distribution curves of particle mass $D(dp)$ over the dust diameters of the ash directly in the air of the ash dump (at a height of 1.5 m).

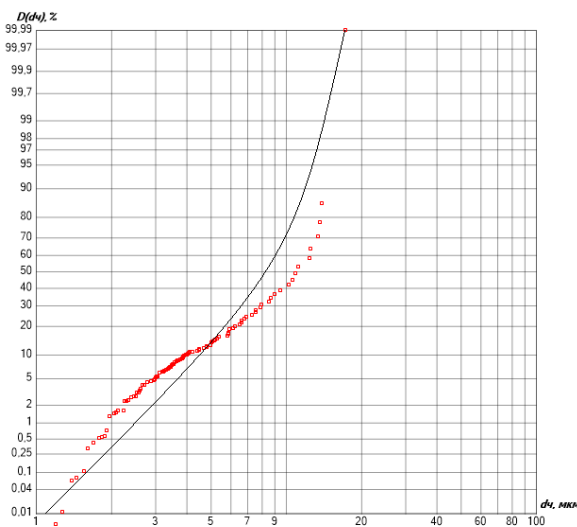


Figure 3. Integral distribution curves of particle mass $D(dp)$ over the dust diameters of the ash at a distance of 50 m from the ash dump a vertical surface (1.5 m high).

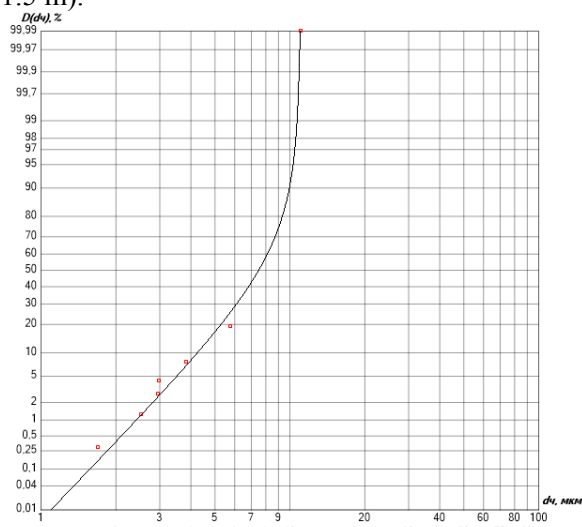


Figure 4. Integral distribution curves of particle mass $D(dp)$ over the dust diameters of the ash at a distance of 50 m from the ash dump a horizontal surface (at a height of 2.0 m).

The results of numerous analyzes carried out by us showed that the dispersion composition of dust in these emissions does not obey Kolmogorov's hypothesis about the logarithmic normal distribution

of the particles mass along the diameters [1]. In the probability-logarithmic coordinate system (x, y) , the particle mass transit function $D(d_p)$ does not take the form of a single straight line. In this connection, the relationship between the coordinates in Cartesian (d_p, D) and logarithmic-normal systems $(\lg d_p, y)$ is expressed as follows (equation 1):

$$D = P_{norm}(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^y e^{-x^2/2} dx \quad (1)$$

As an example, let us consider the results of an approximation for the processing of experimental data on the fractional integrated mass distribution for dust particles entering the atmospheric air from the ash dump at a distance of 50 m from the source at a wind speed of 5.0 m / s. Let's compare the results with the results given in [1] at a wind speed of 4.7 m / s.

3. Mathematical processing of results

For mathematical processing of variance analysis results, a variant of the approximation of the passage function by a three-link linear spline was considered.

As noted in [1], this option was the best - the approximation error did not exceed 20%. The experimental values of the integral distribution function of the particles mass over the diameters, sometimes called the passage function, were a three-link spline of three linear sections. The problem of finding the angular coefficients of these lines (k_1, k_2, k_3) in the probabilistic-logarithmic coordinate system for given abscissa of the "break" points (x_0, y_0) and (x_{cr}, y_{cr}) was reduced to the optimal planning problem. We introduced a vector θ composed of unknown quantities such that $\theta t = (y_0, k_1, k_2, k_3)$ and some matrix F (equation 2):

$$F = \begin{pmatrix} 1 & (x_1 - x_0) & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & (x_n - x_0) & 0 & 0 \\ 1 & 0 & (x_{n+1} - x_0) & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & (x_p - x_0) & 0 \\ 1 & 0 & (x_{kp} - x_0) & (x_{p+1} - x_{kp}) \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & (x_{kp} - x_0) & (x_N - x_{kp}) \end{pmatrix} \quad (2)$$

Then, for the known vectors Y and X , composed of the experimental values of the probability integral quantile from D_i and of the particle diameter logarithm $d_i \lg d_i$, using the Gauss-Markov theorem, for each pair (d_0, d_{kv}) a set of parameters (y_0, k_1, k_2, k_3) at which the error value is minimal was found.

Using this variant of approximation, for each of the four points we obtain the characteristics of the dispersed composition of dust entering the atmospheric air from the ash dump.

The proposed method for describing the dispersed dust composition in the air emissions from the ash dump allows to reduce the maximum error to 5-10%, and can be used to estimate the fractional composition of dust from other dust emission sources, as well as to calculate the concentrations of particles $PM_{2.5}$ and PM_{10} [1].

4. Conclusions

1. It is proved that the dispersed composition of dust in emissions from the ash dump is subject to a truncated log-normal law. Three-link linear splines are useful for interpolating the function of the particle mass distribution.
2. The dispersed composition of dust settling on a vertical surface at a distance of 50 m from the ash dump is described by a truncated logarithmic normal law.

3. Dust floating in the atmosphere at a distance of 50 m from the ash dump and settled on the horizontal surface, a truncated normal law may be applicable for particles with an equivalent diameter greater than $2.5\text{ }\mu\text{m}$ ($\text{PM}_{2.5}$). The maximum size of the particles in the air on the territory of the ash dump is $41\text{ }\mu\text{m}$, at a distance of 50 m from the ash dump on a vertical surface - $11\text{ }\mu\text{m}$, at a distance of 50 m from the ash dump on a horizontal surface - $27\text{ }\mu\text{m}$; in the ambient air $16\text{ }\mu\text{m}$.

4. In all the cases under consideration, the dependences characterizing the integral distribution functions of the particle mass by the diameters can be obtained on the basis of approximation of the results of the measurement data by three-link and four-link linear splines.

5. Comparison of the results obtained by the authors with the studies carried out earlier suggests that the dust settling at a distance of 50 m from the ash dump of the boiler house is smaller ($d_{50} = 13\text{ }\mu\text{m}$, $d_{\text{max}} = 16\text{ }\mu\text{m}$) than, for example, from the State District Power Plant ($d_{50} = 21\text{ }\mu\text{m}$, $d_{\text{max}} = 31\text{ }\mu\text{m}$). In this case, the dust settling on the horizontal surface is larger ($d_{50} = 20\text{ }\mu\text{m}$, $d_{\text{max}} = 29\text{ }\mu\text{m}$) than the dust settling on the vertical surface ($d_{50} = 7.5\text{ }\mu\text{m}$, $d_{\text{max}} = 11\text{ }\mu\text{m}$).

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