Application of theoretical studies for a description of the process of dust subsidence of chrysotile-asbestos dust and cement dust

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Abstract. The authors have sampled dust samples in the modelling shop of the enterprise, that produced asbestos cement products, performed the dispersal analysis of chrysotile asbestos dust and cement dust, built areas of integral curves particle mass distribution by diameters for aspiration systems, general exhaust ventilation and sanitary protection zone. For description of dispersal composition of dust were used two-link splines in log-probabilistic coordinate system. Carried out a mathematical evaluation of these functions as random. The method of “dissection” is used for their description.

Introduction
Dispersal composition of the dust can be described by using various methods. To theoretical dependencies can be attributed: log-normal distribution and formula of Romashov, Zagustin, Griffiths. Based on experimental dependencies, can be attributed formula of Martin - Andersen, Godin, Roshchin, Rambler, Swenson - Avdeev, Shifrin, Petrovyla. Research data on the dispersal composition of the dust widely presented in academic papers of P.A. Kouzov, E.I. Boguslavsky, V.A. Kharchenko, V.N. Azarov [1,2].

Log-normal distribution is essential in order to systematize the results of dispersal dust analysis. According to [3], particle distribution asymptotically tends to log-normal, in which normally distributed not the particle diameter, but its logarithm.

Pass function \( D(d) \) and density \( \varphi(d) \) log-normal distribution of the mass of particles by diameter is expressed through the formula:

\[
D(d) = \frac{1}{\sqrt{2\pi} \sigma_{\text{lg}} } \int_{-\infty}^{\text{lgd}_{50}} \exp \left[ - \frac{ (\text{lgd} - \text{lgd}_{50})^2 }{ 2 (\text{lgd}_{50})^2 } \right] \text{d lg d},
\]

where \( \text{lgd}_{50} \) - the median of the distribution;
\( \text{lgd} \) - standard deviation of logarithms diameters.

However, larger particles can’t reach the aspiration system, because the value of their hovering speed exceeds the speed of local suction constructions [4]. In this case, to describe results of dispersal composition of the dust used a truncated version of log-normal distribution. Further, curves are approximated by two-link, three-link or four-link spline with the least square method [5].

Identification of dispersal composition of the asbestos cement dust
The authors have sampled dust samples in the modelling shop of the enterprise, that produced asbestos cement products to determine the dispersal composition [6,7]. Dustiness was measured near the transfer unit and belt conveyor in 12 points. The research was carried out using program SpotExplorer. Basic parameters for different fractions (fig. 1) are shown in table 1. The graphic image of the results can be represented as integral distribution functions $D(d\chi)$ particle masses by diameter $d\chi$, which are following the truncated log-normal law [8, 9].

According to the Kolmogorov hypothesis, the integral distribution functions $D(d\chi)$ particle masses by diameter $d\chi$ for dust, formed as a result of crushing, abrasion, etc., generally described by a log-normal function. However, in some works [10] was demonstrated, that dust in the air of the working zone, the aspiration system following a truncated log-normal law and can be approximately described by a two-tier or three-tier spline.

Based on the results of measurements of the dispersal composition of asbestos cement dust, that were taken in the air of working zone of modelling shop, the authors have built integral distribution curves $D(d\chi)$ particle masses by diameter (figure1). To describe the dispersal composition of dust were used two-link spline in log-probabilistic coordinate system, one part of which is smaller fractions, and the other - larger. Coordinates of the hub points, angle of inclination of the straight lines were determined by the least square method [11, 12].

**Table 1.** The values of the median of the distribution and standard deviation of logarithms diameters from their average value for small and large fractions of asbestos cement dust, coordinates of the hub point

| № of point | Small fractions | Coordinates of the hub point | Large fractions |
|------------|----------------|-----------------------------|-----------------|
|            | $d_{50}$ | $lg \sigma$ | $d_0$ | $d_0$ | $d_{50}$ | $lg \sigma$ |
| 1          | 2       | 3               | 4       | 5       | 6       | 7               |
| 2          | 22      | 1.09            | 36      | 51      | 28      | 0.19            |
| 3          | 33      | 0.82            | 29      | 63      | 36      | 0.19            |
| 4          | 38      | 1.01            | 29      | 41      | 31      | 0.26            |
| 5          | 40      | 1.06            | 24      | 32      | 29      | 0.35            |
| 6          | 29      | 0.91            | 29      | 51      | 28      | 0.12            |
| 7          | 23      | 1.02            | 22      | 49      | 21      | 0.17            |
| 8          | 19      | 0.85            | 20      | 51      | 18      | 0.15            |
| 9          | 21      | 0.83            | 31      | 69      | 26      | 0.19            |
| 10         | 28      | 0.85            | 30      | 51      | 28      | 0.10            |
|            | 101     | 1.42            | 67      | 43      | 54      | 0.08            |
Figure 1. Integral distribution curves $D(dч)$ particle masses by diameter: 2. 4. 5. 6. 9. 10. 11 – around the conveyor. 1. 3. 7. 12 – around the hub point.

Mathematical processing of the description of the process of dust subsidence of chrysotile-asbestos dust and cement dust

However, obtained data can’t represent an accurate picture due to the differences of the values of the integral distribution curves $D(dч)$ particle masses by diameter. The reason for this is that integral distribution curves $D(dч)$ particle masses by diameter are strongly affected by proportion of large particles which don’t have sustainable distribution.

Consequently, it’s better to assess these functions not as deterministic but as random.

To describe a random function, the “dissection” method was used [13, 14]. According to the method, dispersal composition takes constant values for small particles and the form of integral distribution curves $D(dч)$ particle masses by diameter determined by the proportion of large fractions.

In order to separate small fractions from the large ones, the mathematical uses following designation: $d_о$ – abscissa of the break point of the graph (hub point).

Then integral distribution curves $D(dч)$ particle masses by diameter for small fractions will be:

$$
D_s(dч) = \begin{cases} 
\frac{100}{D(dч_o)} D(dч), & \text{если } d_ч \leq d_о \\
0, & \text{если } d_ч > d_о 
\end{cases}
$$

For large fractions:

$$
D_l(dч) = \begin{cases} 
0, & \text{если } d_ч \leq d_о \\
\frac{100}{100 - D(dч_o)} D(dч), & \text{если } d_ч > d_о 
\end{cases}
$$

With the usage of "dissection" method were built integral distribution curves $D(dч)$ particle masses by diameter for particles a diameter less than 20 μm (microns) and more than 20 μm. This dissection was used to every curve, and the obtained integral distribution curves $D(dч)$ particle masses by diameter represented in figure 2.

In the result of construction, it turned out, that all 12 curves on the site (0. 20) almost coincided (fig.2). Consequently, for particles of small diameter the dispersal composition has constant values and this dust can be defined as a deterministic curve. [15, 16].

Furthermore, the authors examined the dust from the aspiration systems of the modelling shop (in local suctions from runners and after cyclones), general exhaust ventilation and in the air of the sanitary protection zone [17]. On the enterprise for producing asbestos cement products applied cyclones CN-15-700. the efficiency of which is 76% [18]. According to the results of dispersal
analysis were built areas of integral distribution curves $D(d_{ч})$ particle masses by diameter for aspiration systems, general exhaust ventilation and the sanitary protection zone (figure 3).

**Figure 2.** Integral distribution curves $D(d_{ч})$ particle masses by diameter of large and small fractions from air samples in the working zone of the modelling shop

**Figure 3.** Areas of integral distribution curves $D(d_{ч})$ particle masses by diameter: 1 – in aspiration system before cleaning in a cyclone; 2 - in aspiration system after cleaning in a cyclone; 3 – in the general exhaust ventilation; 4 – in the sanitary protection zone

**Summary**
The graphs that shown on fig.3. have the form of truncated logarithmic curves. In aspiration systems median diameter ($d_{50}$) changes from 32 to 49 μm. in ventilation systems - from 11 to 17 μm. in the sanitary protection zone - from 3 to 6.1 μm. Particle size of dust varies from 3 to 100 μm.

Studies show that the dispersal composition of dust in the air of the working zone for particles up to 20 μm in size following a log-normal distribution and can be represented as a deterministic curve. Large particles with the size more than 20 μm are distributed in a form of random functions. for which it is not possible to choose the distribution law.

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