About the assessment of the chrisothal asbestos dust slip into the atmosphere as a random function

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Abstract. The paper presents the study of the fractional efficiency of asbestos-cement dust slip from the aspiration system as a random function. Total slip was considered as a random variable. Also dispersed analysis of dust from the aspiration systems serving the process equipment and processes was performed. Examples of the function of the dust passage in the production of asbestos-cement products before cleaning in the CSF apparatus and after cleaning showed that the total dust slip in CSF apparatuses as a random value corresponds to the normal distribution law. The density characteristics and the distribution function for the total asbestos cement dust slip penetration are determined. The range of variation of the random dust slip function for CSF-150 and CSF-300 apparatuses is presented. Recommendations are given to reduce the negative impact of the dust factor in the air of enterprise working areas.

1. Introduction
In the production of materials from chrisothal asbestos and cement there is a significant formation of dust of various fractions. At the same time, mechanical cleaning technologies are used to combat the dust factor, due to the sedimentation of particles under the action of external forces and cleaning with the help of filters, due to the retention of particles in the filter material. In accordance with the structural features of asbestos fibres, as well as the specifics of production, the smallest fractions with a particle diameter of less than 10 microns and less than 2.5 microns cannot be captured. The concentration of asbestos cement dust in the air of the working area at a number of enterprises exceeds the maximum permissible value by 5 times, and the concentration at the border of the sanitary protection zone of the enterprise has a two-fold excess of the standards [1].

To develop long-term solutions to the problem of protection from dust emissions at workplaces, it is necessary to study their chemical composition, properties of chrisothal asbestos, analyse the dispersion composition, dust characteristics, as well as examine dusting processes and evaluate the efficiency of dust slip in dust collectors proposed for implementation.

2. The study of the fractional efficiency of dust slip
The study of the characteristics of chrisothal asbestos dust is a relevant and important topic for solving environmental safety issues. It is very important to know the fractional efficiency of dust slippage. To do this, the authors examined the aspiration systems serving the process equipment and processes, and
also took dust samples at the border of the sanitary protection zone of an enterprise for the production of asbestos-cement products in the Volgograd region. Dispersed analysis of asbestos-cement dust samples at the inlet and outlet of the CSF dust collector was carried out [2]. The graphical representation of the results is given in the form of \( D(dx) \) integral distribution functions of the mass of chrysotile dust particles over the equivalent diameters of \( dx \) passage functions (figures 1, 2).

Two modifications of dust collectors on counter-swirling flows were investigated: CSF-150 and CSF-300, where the numbers indicate the diameter of the apparatus. The cost ratio in the upper and lower inputs of the apparatus was set optimally [3]. At the same time, dust was taken from the existing aspiration system. The total slip in the first case was 0.037, in the second - 0.049. The diameter of the fractional efficiency is presented in figure 3.

Further, the total slip \( \varepsilon_\Sigma \), which is a random variable, was determined [4]. A sample was obtained of the values of this random variable, the volume of which is equal to 26. From the sample, parameter estimates were found, which are listed in table 1.

| Parameter                | Parameter designations | Estimate values |
|--------------------------|------------------------|-----------------|
| Average value            | \( M_e \)              | 0.05207         |
| Dispersion               | \( D \)                | 0.000046        |
| Standard deviation       | \( \sigma \)           | 0.00678         |
| Mode                     | \( Mo \)               | 0.058           |
| Median                   | \( Me \)               | 0.0545          |
Figure 2. The histogram of the frequencies of the random variable total slippage and the normal distribution.

By the form of the histogram (figure 2) and, taking into account that the average value, mode and median are close to each other, the normal law was checked using the Pearson $\chi^2$ test at a significance level of $\alpha = 0.05$ [5,6]. The entire sample was divided into 12 groups and the statistical value was obtained: $\chi^2 = 1.89023$. According to the table of critical points $\chi^2$, by the significance level $\alpha = 0.5$ and the number of degrees of freedom $r = 9$, we determine the critical value $\chi^2_{cr} = 16.9$. Since $\chi^2 < \chi^2_{cr}$, then at the significance level $\alpha = 0.5$, the hypothesis of a normal law is consistent with experimental data.

The density function and the distribution function for the total slippage will be:

$$f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-M\varepsilon)^2}{2\sigma^2}} = \frac{1}{0.00678 \sqrt{2\pi}} e^{-\frac{(x-0.0521)^2}{0.00678}};$$

$$F(x) = 0.5 + \Phi\left(\frac{x-M\varepsilon}{\sigma}\right) = 0.5 + \Phi\left(\frac{x-0.0521}{0.00678}\right),$$

where $\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_0^x e^{-\frac{t^2}{2}} dt$ - Laplace integral function, $M\varepsilon$ - average value, $\sigma$ - standard deviation.

Thus, the total slip as a random variable has a normal law with an average value of $M\varepsilon = 0.0521$ and a standard deviation of $\sigma = 0.00678$.

Tangents at points every 0.5 µm were drawn to the integral curves of the distribution $D(d_d)$ of the particle mass of the cement dust over the diameters $d_d$ at the inlet and exit of the CSF apparatus and the values of $F_{out,in}$ according to the formula:

$$F_{out,in} = \frac{F(d)}{d}$$

where $F(d)$ – dust passage function in the production of asbestos-cement products, $d$ – particle diameter of asbestos cement dust.

The obtained values are inserted into the formula of V N Azarov to determine the effective dust slip [7]:

$$\varepsilon = \varepsilon \Sigma \frac{dF_{out}}{d\varepsilon p} \frac{d\varepsilon p}{d\varepsilon in}.$$
where \( \varepsilon_{\Sigma} \) - total asbestos cement dust slip, \( F_{\text{out}} \) - the value of the function of the passage at the exit of the CSF apparatus, \( F_{\text{in}} \) - the value of the function of the passage at the entrance to the CSF apparatus, \( d_p \) – particle diameter, \( \mu m \).

Further, based on the results of the calculation, the range of variation of the random slip function was obtained for the CSF-150 and CSF-300 apparatus (figure 3).

![Figure 3](image-url)

**Figure 3.** Ranges of change in the random function of asbestos cement dust slip: 1 - for CSF-150 apparatus (total slip 0.037), 2 – for CSF-300 apparatus (total slip 0.049).

Analysis of the experimental data (figure 3) shows that for the regression equation of the average values of the random function of the slip \( \varepsilon \) of asbestos cement dust from the diameter of its particles for the dust collectors CSF-150 and CSF-300 from several proposed options for dependencies the most preferred function turned out to be the linear function of the form:

\[
\varepsilon = ce^{-\frac{(\log d_1-a)^2}{b}},
\]

where \( a, b, c \) – experimental coefficients, \( d_1 \) - particle diameter divided by 1 \( \mu m \). For CSF-150 it changed from 3.5 to 9, for CSF-300: from 4 to 15.5.

To determine the coefficients \( c, a, \) and \( b \) in this formula, the non-linear Leuvenberg-Markard least squares method was used, which is more efficient and accurate than most general optimization algorithms [8]. At a significance level of \( \alpha = 0.05 \), results were obtained (table 2).

| Assessed parameters | CSF 150 | CSF 300 |
|---------------------|---------|---------|
| c                   | 0.3356  | 1.0099  |
| a                   | 0.3073  | 0.5458  |
| b                   | 0.1860  | 0.1273  |
In this case, the multiple correlation coefficient for the CSF-150 dust collector: \( R = 0.92 \), and for the CSF-300 dust collector: \( R = 0.99 \). This indicates that there is a high correlation between the random function of the slip \( \varepsilon \) of asbestos cement dust and the diameter \( d \) of its particles [9].

3. Conclusions
Based on the dispersed composition, we can judge about the presence of fine dust in the working area, as well as estimate the percentage of PM\(_{10}\) and PM\(_{2.5}\) particles in the total concentration of harmful pollutants. In figure 1, the values of the proportion of asbestos-cement dust particles in the aspiration system before cleaning in the CSF apparatus are changed for PM\(_{10}\) from 1.3% to 2.5%; PM\(_{2.5}\) particles are not present in the working area air. In the aspiration system after cleaning, only PM\(_{2.5}\) particles are determined in the CSF apparatus, the percentage of which is from 6% to 10% of the total mass of dust.

Therefore, it can be argued that emissions from the production of asbestos-cement products are characterized by a high percentage of fine dust.

Studies have shown that the fractional efficiency of the CSF-150 apparatus for chrysotile dust and cement can be expressed by functions of the density and the mass distribution of particles of equivalent diameters, where \( x = \lg \):

\[
    f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-M_\varepsilon)^2}{2\sigma^2}},
\]

\[
    F(x) = 0.5 + \Phi\left(\frac{x-M_\varepsilon}{\sigma}\right).
\]

The determined total slip, as a random variable, has a normal law with an average value of \( M_\varepsilon = 0.0521 \) and a standard deviation of \( \sigma = 0.00678 \). Similarly, for the CSF-300 apparatus, the slip function is shown in figure 3. A regression equation was obtained for the average values of the random slip function \( \varepsilon \) of asbestos cement dust from the diameter \( d \) of its particles for the CSF-150 and CSF-300 dust collectors, defined by a model of a nonlinear function of the form:

\[
    \varepsilon = ce^{-\frac{(\lg d - a)^2}{b}}.
\]

The parameters of the random function of the breakthrough were estimated, and experimental coefficients were obtained.

It should be noted that the research results do not give grounds to talk about an increased risk when exposed to chrysotile asbestos in controlled conditions.

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