The effective air exchange organization scheme selection in the working area at the asbestos-cement products manufacturing enterprises

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Abstract. The article explores various schemes of air exchange organizing in the molding shop of an enterprise for the asbestos-cement product’s manufacturing. To find the air exchange value, a system of balance equations for the workshop and the working area is proposed and solved, characterizing coefficients are determined. Based on the data on the disperse composition of dust and aerodynamic characteristics, the optimal air exchange scheme for the enterprises producing building materials is proposed.

Introduction
In determining the amount of fresh air supplied to the working area in the building materials’ production, the air exchange arrangements are of great importance. For the workshops with a significant emission of dust, which includes molding, SNiP [1] recommends a scheme for organizing air exchange, providing for the supply of fresh air according to the “top-down” scheme. In addition, a number of the researchers [2-8] suggest supplying fresh air directly to the working area and removing it from the upper zone.

To assess the dust concentration distribution laws and choose the air exchange optimal organization in the area of the type in question, the authors conducted the pilot industrial studies on the basis of the existing enterprise for the asbestos-cement products manufacturing. The size of the molding workshop was 18-432 m, height 10.8 m. Using a flexible hose system, air distribution was organized in various ways (Figure 1). At the same time, the concentrations distribution measurements in the air over the workshop height were carried out (Figure 2).

Evaluation of the asbestos-cement concentration distribution dust patterns in the production area and the air exchange optimal organization choice
Figure 2a shows the distribution curve of the dust concentrations obtained with the concentrated air supply. The studies have shown that an increase in relative concentrations is observed in the lower part of the workshop, at the level of the supply jet, the concentrations decrease in the removed air and become close to the concentration in the working area [9-14].
Figure 1. The air distribution organization scheme in various ways in the molding shop of an enterprise for the asbestos-cement products manufacturing: a) concentrated air distribution; b) inclined air supply; c) air supply to the working area through the ejection panel air distributor; d) air supply to the working area by the “flooding” method.
Fig. 2. Dust concentration distribution over the height of the molding workshop:
a) with concentrated air distribution, b) when supplying air with inclined jets, c) when supplying air to the working area through the ejection panel air distributor, d) when air is supplied to the working area according to the “flooding” method.

In order to increase the general ventilation’s efficiency, a method to supply air directly to the working area or in the working area direction was used. So, when air is exhausted with the inclined jets from a height of 5 m in the direction of the working area (Fig. 1b, 2b), it is possible to increase air exchange coefficients, but for the workshops with high dust generation, to which molding is included, this method is almost not used [15-19].

The greatest effect of the supply air use is observed when it is distributed directly to the working area. To supply the air to the working area, the authors used the ejection air distributor panels, which have a high ejection ability and provide fast attenuation of velocities at the device exit [2, 3, 6]. This allows for significant specific air loads to install the air distributors in close proximity to the working area.

Building codes set the air speed in the working area of such workshops to 0.4 m/s [1]. An increase in the air exchange coefficient can be achieved by releasing air directly into the working area with low-ejecting jets [3]. In this case, the supply stream at the speed of 0.25-0.35 m/s develops along the floor surface without actively involving the polluted air from the upper zone of the room and “flooding” the working area, displaces the exhaust air (Fig. 1c, d) In order to prevent the jet from floating up, the supply air temperature should be 1–2 °C lower than the room temperature [20-24].

SNiP [1] recommends the following formula for calculating the fresh air amount

\[ L = L_{WZ} + \left( \frac{m_{po} - L_{wz} \cdot (q_{wz} - q_{in})}{q_{l} - q_{in}} \right) \]  

(1)

where \( L_{WZ} \) - is the flow rate of the air removed from the serviced or working area of the room by the local exhaust systems, m³/h;

\( m_{po} \) - is the consumption of each of the harmful substances entering the room air, mg/h;

\( q_{wz} \) - defines the concentration of harmful substances in the air removed from the working area, mg/m³;

\( q_{in} \) - defines the concentration of the harmful substance in the air supplied to the room, mg/m³;

\( q_{l} \) - is the concentration of harmful substances in air removed outside the working area, mg/m³.

Thus, with the air exchange “bottom-up” organization, i.e. the method of supplying fresh air directly to the working area and removing it from the upper zone (Fig. 1c, 2c and 1d, 2d), to determine
the fresh air $L_0$ amount it is necessary to consider a system of two equations representing a dust balance, compiled separately for the entire workshop and working area

\[
\begin{align*}
&L_0 q_{in} + K_{it} L_0 q_{wt} + K_{1wt} M_{m.o.} + K_{sus} M_{m.o.} = \\
&L_{asp} q_{ef.} + \left[\left(K_{it.} + 1\right) L_0 - L_{asp}\right] \left[q_{ef.} + \lambda \left(q_{wt.} - q_{ef.}\right)\right] ; \\
&L_0 q_{in} + K_{sus} M_{m.o.} + K_{2wt} M_{m.o.} = L_{asp} q_{ef.} + \left(L_0 - L_{asp}\right) q_{wt}.
\end{align*}
\]

where: $\lambda$ – is the coefficient characterizing the change in dust concentration outside the working area (based on pilot studies for Fig. 1 in: $\lambda = 0.6$; for Fig. 1 d: $\lambda = 0.35$); $M_{kn} -$ is the dust mass knocked out of the equipment, with a coefficient $K_1$ showing the proportion of dust that becomes suspended in the working area; $K_2$ shows the proportion of dust that becomes suspended in the upper area of the room; $K_{sus}$ – is the proportion of dust in suspension under certain patterns of air exchange (for the molding shops - 4-5% of the total dust emission); $K_p$ is calculated on the basis of the jets theory [6] and varies from 0.35 when supplied by the “flooding” method to 5.0 when supplied by inclined jets.

Solving a system of equations for the air exchange $L_0$ amount reduced to a quadratic equation, the solution of which makes it possible to determine the air exchange amount. So, with the “bottom-up” air exchange scheme, we obtain the following equation:

\[
a \left(\frac{L_0}{L_{asp}}\right)^2 + b \left(\frac{L_0}{L_{asp}}\right) + c = 0
\]

where 
\[
a = \left(\lambda K_{it} - K_{it.} + \lambda\right)
\]
\[
b = \frac{\left(1 - \lambda\right) M_2 - \lambda M_2 + M_1}{q_{p.z.} - q_{n.pum}} L_{asp} - \left(1 - \lambda\right) \left(2 + K_{it.}\right);
\]
\[
c = 1 + \frac{M_1 + \lambda M_2}{q_{c.f} - q_{n.pum}} L_{asp}.
\]

\[
M_1 = K_{1wt} M_{m.o.} + K_{sus} M_{m.o.};
\]
\[
M_2 = K_{sus} M_{m.o.} + K_{2wt} M_{m.o.} - L_{asp} q_{ef}.
\]

This equation actually differs from the formula (L 2) from SNiP [1] in that the dust concentration value in the removed air is excluded from it $c_{rel}$, which depends on the above-mentioned factors. Complex $a$ depends on the coefficients $K_{it.}$ and $\lambda$. To find the complexes $b$ and $c$ first $M_{kn}$ should be determined by the method of finding a mass of the dust knocked out of the technological equipment [15].

Summary
The studies’ results analysis of the dispersed composition and aerodynamic characteristics of asbestos-cement dust made it possible to determine the coefficients included in the complexes $a$ and $c$ with the formulas (3) $K_{1wt}$ and $K_{2wt}$, which amounted to 0.06 and 0.035 of the total amounts of the dust released from the technological equipment. The pilot tests carried out under various operating modes of
technological equipment and fresh air supply methods made it possible to conclude that when air is supplied by the “flooding” method of the working area in the formula (2), the value $K_{\text{sup}} = 0.04$.

Thus, the authors specified the air exchange amount and selected the optimal scheme for its organization in the working area at the enterprises producing chrysotile asbestos and cement products.

Based on the data on the dust dispersed composition, the aerodynamic characteristics, effective for the construction industry enterprises, the “bottom-up” air exchange scheme is used, with fresh air supplied by the method of the working area “flooding”.

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