Modeling the Laws of Airborne Distribution of Dust Particles Generated in Primary Cotton Processing Plants

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ABSTRACT

In this article was given ideas on mathematical modeling of the laws of airborne distribution of dust particles generated in primary cotton processing plants, the laws of airborne distribution of various chemically harmful dust particles, as well as the physical variables of the air environment views on the modeling of dust particle dispersion processes in the working zone, such as stability, air flow rate, numerical values of indicators

Keywords: Chemical contaminants, dust, working zone, dust particles, particle size, distribution laws, modeling, Gaussian type, analytical analysis

In the context of globalization, the sharp intensification of production, the strengthening of the competitive environment began to place more and more demands on the quality of technological processes. At present, models of airborne dispersion of various dusts and chemical pollutants are widely used in world practice. However, the laws governing the distribution of dust concentrations in primary cotton processing plants have not been sufficiently studied. In this regard, it is important to analyze the distribution of dust particles generated during the processing of cotton in the air of the working zone, to develop their mathematical models and to give optimal solutions. The basis of mathematical modeling of the distribution of dust particles in the air of the working zone is a system of differential equations (2.2) It should be borne in mind that the analytical solution of this system of differential equations can be obtained only in special cases. Dust particles enter the air of the working zone at a certain speed and temperature, which usually differs from the corresponding properties of the natural state of the air in the working zone. This situation is also a model for modeling dust particle dispersion processes in the work area, such as physical variables of the air environment (thermal stability, air flow rate, numerical values of indicators, etc.) that affect the passage and dispersion of dust particles, a number of assumptions need to be made, in addition to a number of other descriptive factors, i.e., dust particles of different sizes that are formed during the processing of cotton.

$$\begin{cases} \frac{\partial C}{\partial t} + u_x \frac{\partial C}{\partial x} = \frac{\partial}{\partial x}\left(N_x \frac{\partial C}{\partial x}\right) - kC + \frac{g(x,y,z,t)}{V} \\ \frac{\partial C}{\partial t} + u_y \frac{\partial C}{\partial y} = \frac{\partial}{\partial y}\left(N_y \frac{\partial C}{\partial y}\right) - kC + \frac{g(x,y,z,t)}{V} \\ \frac{\partial C}{\partial t} + u_z \frac{\partial C}{\partial z} = \frac{\partial}{\partial z}\left(N_z \frac{\partial C}{\partial z}\right) - kC + \frac{g(x,y,z,t)}{V} \end{cases}$$

(2.2)

Here , $u_{x,y,z}$ - x, y, z air velocity along the axes;

$N_{x,y,z}$ - the rate of dispersion of toxic substances along the corresponding axis (x, y, z);

k - The coefficient of variation of the concentration of toxic substances as a result of metabolism in the air;

$g(x, y, z, t)$ - A generalized expression describing the process of cyclone air purification in a primary cotton processing plant;

V- Working zone size.

The system of equations of transport and diffusion (2.2) is a general expression containing a set of variables necessary to describe the physical process of distribution of dust particles formed as a result of the initial processing of cotton. However, it fully describes the physical process itself, and the solution of this system allows to determine the spatial coordinates and the concentration of dust particles depending on time. This decision requires knowledge of the known variables that characterize the state of the air environment and mentioned above (they affect the concentration of dust particles in the workplace). In the special case of the dispersion of dust particles in the absence of external influences, the diffusion current is proportional to its concentration due to Fick's laws. [1]. The expression of the first Fick's law [2,3] describing the process of diffusion in stationary mode has the following form:

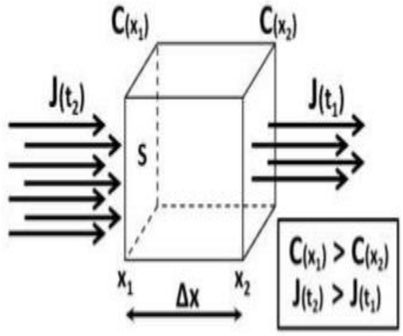
$J = -D\nabla C$ *(2.3)*

In this case, J is the current density of the dispersing substance;

D is the proportionality coefficient

∇C-gradient concentration, $\nabla = \frac{\partial}{\partial x}\hat{\imath} + \frac{\partial}{\partial y}\hat{\jmath} + \frac{\partial}{\partial z}\hat{k}$.

The use of this law for the experimental determination of the D-coefficient is possible only for the steady state, that is, if the concentration gradient does not change over time, we use the law of conservation of energy to form the second law of Fick, taking into account the first law. The second law describes the process of stationary diffusion in space [1]. Consider the non-stationary concentration field and the elemental volume. In this case, the concentration of the substance C varies in the elemental



volume (Fig. 1).

Figure 1. - Changes in the concentration of a substance in an elemental volume

Using the laws of conservation, $[C_{(x1)} - C_{(x2)}]S\Delta x = [J_{(t2)} - J_{(t1)}]S\Delta t$

the change in the concentration of a substance over time "x" and "x + dx" by the difference in current density. $\frac{\partial C}{\partial t} = -\frac{\partial J}{\partial x}$ *(2.4)*

because with one-dimensional diffusion

$$J = -D\frac{\partial C}{\partial x}$$

Here we obtain

$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$ *(2.5)*

In general, Fick's second law takes the following form [4,5]:

$\frac{\partial C}{\partial t} = \sum_{i=1}^{3} D\frac{\partial^2 C}{\partial x_i^2} = D\Delta C$, (2.6)

Here: $\Delta = \nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ - Laplace operators,

The first and second Fick laws (2.3-2.6) cannot determine the structure of the proportionality coefficient "D". If the problem of determining the structure of the coefficient D is solved, then equations (2.3-2.6) allow to solve any problem of dispersion of dust particles in air. However, in order to solve these problems, it is necessary to formulate initial and boundary conditions [1]. In the process of diffusion of dust particles into the air of the working zone, ideal conditions are assumed that the diffusion coefficient "D" remains constant and does not depend on the concentration of these substances. In this case, the solution of the differential equation (2.5) corresponding to the one-dimensional case has the following form:

$$C= \frac{k'}{t^{1/2}} e^{-\frac{x^2}{4Dt}} \quad (2.7)$$

Proof of this is:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial t}\left[\frac{k'}{t^{\frac{1}{2}}} e^{-\frac{x^2}{4DT}}\right] = k'\left[e^{-\frac{x^2}{4DT}} \frac{\partial}{\partial t}\left(\frac{1}{t^{\frac{1}{2}}}\right) + \frac{1}{t^{\frac{1}{2}}}\frac{\partial}{\partial t}\left(e^{-\frac{x^2}{4DT}}\right)\right]$$

$$= k'\left[-\frac{1}{2t^{\frac{3}{2}}} e^{-\frac{x^2}{4DT}} + \left(\frac{1}{t^{1/2}}\right)\left(\frac{-x^2}{4D}\right)\left(\frac{-1}{t^2}\right) e^{-\frac{x^2}{4DT}}\right]$$

$$= k'\left[-\frac{1}{2t^{\frac{3}{2}}} e^{-\frac{x^2}{4DT}} + \frac{1}{t^{1/2}}\left(\frac{1}{2t}\right)\left(\frac{x^2}{2D}\right)\left(\frac{1}{t}\right) e^{-\frac{x^2}{4DT}}\right]$$

$$= k'\left[-\frac{1}{2t^{\frac{3}{2}}} e^{-\frac{x^2}{4DT}} + \left(\frac{1}{2t^{3/2}}\right)\left(\frac{x^2}{2Dt}\right) e^{-\frac{x^2}{4DT}}\right] = \frac{k' e^{-\frac{x^2}{4DT}}}{2t^{3/2}}\left[-1 + \frac{x^2}{2Dt}\right]$$

$$D\frac{\partial^2 C}{\partial x^2} = D\frac{\partial}{\partial x}\left\{\frac{\partial}{\partial x}\left[\frac{k'}{t^{1/2}} e^{-\frac{x^2}{4DT}}\right]\right\} = D\frac{k'}{t^{1/2}}\frac{\partial}{\partial x}\left\{\frac{\partial}{\partial x}\left[e^{-\frac{x^2}{4DT}}\right]\right\} = D\frac{k'}{t^{1/2}}\frac{\partial}{\partial x}\left\{\frac{-2x}{4DT}\left[e^{-\frac{x^2}{4DT}}\right]\right\}$$

$$= -\frac{k'}{2t^{\frac{3}{2}}}\frac{\partial}{\partial x}\left\{x e^{-\frac{x^2}{4DT}}\right\} = -\frac{k'}{2t^{\frac{3}{2}}}\left\{e^{-\frac{x^2}{4DT}} + x\left(-\frac{2x}{4Dt}\right) e^{-\frac{x^2}{4DT}}\right\} = \frac{k' e^{-\frac{x^2}{4DT}}}{2t^{3/2}}\left[-1 + \frac{x^2}{2Dt}\right]$$

This function can be seen as a probability function. It initially corresponds to a system with a concentration of C_0 at a given point x_0, from where the dust particles propagate to $x = \pm\infty$. The change in the concentration of dust particles according to the solution of the differential equation of diffusion of gases in a one-dimensional state is shown in Figure 2.

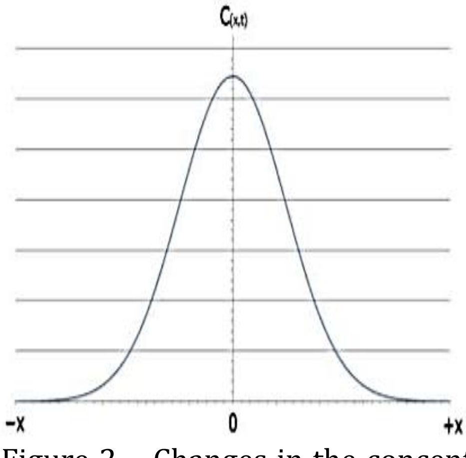


Figure 2. - Changes in the concentration of dust particles in accordance with the solution of the differential equation of diffusion of gases in a one-dimensional state

Equation (2.6) corresponds to a Gauss-type solution as in Equation (2.1).

However, after determining the rate of dispersal of dust particles generated during the processing of cotton in the air of the working zone, it is clear that Equation (2.6) can be taken as a starting point to find a solution to Equation (2.2). When considering a mathematical apparatus describing the processes of dispersion of dust particles in air, it should be borne in mind that there is no single apparatus describing all the processes of dispersion of dust particles in air.

However, there are a number of analytical and experimental solutions in this area. The model created above involves the process of dispersing dust particles during the initial processing of cotton. Obtaining a mathematical expression describing the process of dispersion of these substances in air requires knowledge of gin and linter, as well as additional transmission and receiving machines and variables that affect the emission process of dust particles. The differential equations described above can be solved by creating mathematical functions that describe these variables and set adequate boundary conditions for the problem under consideration. These parameters should be experimentally evaluated when setting the problem of determining the mass of the dust particle entering the workplace per unit time, its size and temperature are unknown. However, in practice, the above parameters can be stochastic features that are difficult to control. This can lead to significant errors in predicting the spread of dust particles in the working zone. This problem can be solved by experimentally finding the function g (xi, t), which allows to solve the differential equations describing the process of dispersal of dust particles in the primary processing plants of cotton.

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