Analysis of disperse composition of the dust in air of working zone of feed mills

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Abstract. In the compound feedstuff production, one of the main problems is the dust emission at all stages of production. The most significant dust emission occurs at the raw materials acceptance stage, where the concentration of dust can be many times higher than the maximum permissible values. The impact of dusts and their capture depends on the dispersed dust composition, and since the raw materials come in different types (bran, wheat, corn, sunflower meal, etc.), the dispersed dust composition is complex. For this reason, it becomes necessary to study their dispersed composition. The article presents the analysis results on some types of the dispersed dust, which generated in the air of the working area on feed mill reception center.

Introduction

The animal husbandry development in Russian Federation leads to expanding the animal feed production - compound feedstuff. In the compound feedstuff production, various raw materials are used, which are mainly represented by bulk materials, for example: wheat, corn, bran, and sunflower and soybean meal. When unloading such materials, there is a significant dust emission into the air in the reception center, caused by ejection of air from the bulk material. Under such conditions, the dust concentration in the air of the working zone can reach values ten times higher than the maximum permissible concentration (6 mg/m³). The harmful effect of dust on workers is due not only to its concentration, but also to its dispersed composition. In particular, particles larger than 10 microns settle quickly enough, and particles up to 10 microns in size create a stable aerosol that workers can inhale. Thus, the determination of the dispersed dusts composition is important from their influence on the health of workers. Therefore, it is now customary to evaluate air dust not only by the total mass, but also by the content of particles up to 2.5 μm and up to 10 μm in size (indicators PM2.5 and PM10), which are prescribed in regulatory documents and for atmospheric air in the Russian Federation are 0.025 mg/m³ and 0.04 mg/m³ (World Health Statistics 2016, Report 2016, Ordinance 2003), respectively, but in the air of the working zone, such standards are not yet available. On the other hand, dust cleaning equipment is designed to capture dust of a certain size, which also explains the need to study the dispersed dusts composition. To determine the operational efficiency of which dispersed composition parameters are often used in the form of average size and standard deviation (Timonin,
A.S. 2003, Cyclones NIIOGAZ 1970, Lazarev, V.A. 2006), which are determined by the dust particle distribution function

**Analysis of the existing researches**

The problem of determining the dust content in the air of the working zone is one of the main ones in modern production. This is due to the dust properties, especially with its dispersed composition. In the literature, studies on the dispersed dusts composition in metallurgy, construction, some food industry and in the atmospheric air of some territories, etc. (Vlasenko et al. 2011, Timonin 2003, Danilova 2017, Williams 2014, Sara et al. 2013). For other cases, in particular, the compound feedstuff production, there is no information about generated dust at the production stages, and at the acceptance of raw material acceptance stage.

**An experimental study of the dispersed dusts composition**

3.1. The purpose of the research is to determine the dispersed dust composition in the air of the feed mill working zone.

The main objectives of the research are:

3.1.1. Substantiate the choice of the microscopic method as a method for studying the dispersed composition of dust, generated at the feed mill receiving center.

3.1.2. To obtain data on the dispersed dusts composition of wheat, sunflower meal, corn and bran as the main raw material used in the compound feedstuff production.

There are various methods for studying the dispersed dusts composition, such as screen analysis, sedimentometry, microscopic analysis (microscopy), centrifugal separation and counting method. None of the methods is universal; each of them has its own advantages and disadvantages. On the research method choice can influence next factors: dust concentration and dust particle size, equipment availability, convenience of collection and preservation of dust samples for further research. All these conditions correspond to the microscopic method, which also allows you to evaluate the appearance of dust particles (color, shape), although there are also disadvantages, such as the complexity during the manual counting, and, as a consequence, the need for complex software.

To conduct the study, dust samples on analytical filters were acquired by the gravimetric method. The study results are shown in table 1, where it can be seen that the dust concentration significantly exceeds the value of the maximum permissible concentration (6 mg/m³). Since the receiving center is only a rain cover with a through passage, parameters such as air temperature, air pressure, relative air humidity, and air velocity at the receiving center depends on the atmosphere state of the atmosphere (Belova et al. 2017) and are not adjusted.

**Table 1. Dust samples characteristics**

| Name of the dust-forming raw materials | Dust concentration, mg/m³ | Air temperature, °C | Air pressure, mmHg Art. | Relative air humidity, % | Air velocity, m / s |
|---------------------------------------|--------------------------|---------------------|------------------------|------------------------|-------------------|
| Bran                                  | 168                      | 23                  | 744.7                  | 50                     | 1                 |
| Sunflower meal                        | 1518                     | 1.8                 | 734                    | 78                     | 1                 |
| Corn                                  | 63                       | 11.5                | 746                    | 67                     | 7                 |
| Wheat                                 | 92                       | -2.5                | 754                    | 46                     | 1.2               |

As equipment and software were used: Micromed 3 microscope, ToupCam 9.0 MP video eyepiece for microscope, Goryaev’s camera, LevenhukLite program, Microsoft Office software package, Compass-3D V12 lite program, Statistica program.
Microphotographs obtained with a microscope and a video eyepiece at a 100 × magnification were saved in .bmp format in the LevenhukLite program. Calibration of real particle sizes in microphotographs was carried out using a Goryaev camera. On calibrated micrographs, the largest linear size of each dust particle was measured using the Compass-3D V12 lite program. The received data was recorded into the spreadsheet of Microsoft Excel program from the Microsoft Office software package. To speed up the data processing in the Statistica program, was tested a hypothesis on the law of the dust particles distribution by their number. An estimate of the parameters of the dust particles distribution by mass was also obtained.

Figures 1 and 2 show, for example, some microphotographs fragments of bran dust, sunflower meal, wheat, and corn.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Dust micrograph fragments: a) bran, b) sunflower meal

**Figure 2.** Dust micrograph fragments: a) wheat, b) corn

Description of figures 1 and 2, where they were processed:
- bran dust particles (Figure 1, a) have a predominantly rounded shape, particles of irregular shape come across, the minimum and maximum particle sizes are 3.12 and 77.9 μm, respectively;
- sunflower meal dust particles (Figure 1, b) have an oblong and irregular shape, the minimum and maximum particle sizes are 3.24 and 254.64 μm, respectively;
- wheat dust particles (Figure 2, a) also have an oblong and irregular shape, the minimum and maximum particle sizes are 4.01 and 65.88 μm, respectively;
- corn dust particles (Figure 2, b) are mainly round or oblong, the minimum and maximum particle sizes are 1.74 and 78.06 μm, respectively.
Determining the dust particles shape is important when more accurately establishing the rotation speed, which is necessary to predict the spread of dust particles in the air. The rotation speed, as a rule, is established either experimentally or determined according to Stokes law, where the particles shape is assumed to be spherical. The velocity of elongated shape particles with the same size is slightly higher than spherical.

Figure 3 and 4 shows histograms of the dust particles distribution by quantity. In each of the histograms, the abscissa axis indicates the intervals of particle sizes in microns, and the ordinate axis shows the percentage of particles that fall into each interval, in%. Based on the obtained histograms, a hypothesis was put forward that the dust particles distribution obeys the log-normal law (Kouzov 1987, Cyclones NIIOGAZ 1970, Lazarev 2006). This hypothesis was chosen: first, by the histograms appearance of the dust particles distribution by quantity; secondly, by the smallest calculated value of the $\chi^2$ criterion among the tested other hypotheses (normal and gamma distributions).

![Figure 3](image-url). Histograms of the dust particles distribution by the amount of: a) bran, b) sunflower meal

![Figure 4](image-url). Histograms of the dust particles distribution by the amount of: a) wheat, b) corn

Subsequently, for use in practical purposes, was assessed the dust dispersion composition by weight. Table 2 and Figures 5 and 6 show the dispersed composition parameters, graphs of the function and distribution density by mass, as well as the PM2.5 and PM10 values. According to the source (Sara et al. 2013) and a number of others, particles up to 2.5 $\mu$m in size are the most dangerous for the body, and particles up to 10 $\mu$m in size can stay in the air for a long time, as a result, they are highly likely to get into the human respiratory system.

**Table 2.** The dispersed dust composition parameters

| Parameter | Dust type |
|-----------|-----------|
|           |           |

4
| Amount of detected particles | Bran  | Sunflower meal | Wheat | Corn |
|-----------------------------|-------|----------------|-------|------|
| 1373                        | 5280  | 19090          | 9110  |      |
| \(\delta_{\text{min}}, \mu m\) | 3.12  | 3.24           | 4.01  | 1.74 |
| \(\delta_{\text{max}}, \mu m\) | 77.9  | 254.64         | 65.88 | 78.06|
| \(\delta_{\text{m}}, \mu m\) | 35.48 | 102.33         | 35.48 | 23.99|
| \(\lg \sigma\)             | 0.375 | 0.21           | 0.17  | 0.265|
| \(R^2\)                     | 0.9963| 0.9973         | 0.9976| 0.9989|
| PM2.5, %/(mg/m³)            | 0.11(0.185) | 8.18·10^{13}(1.24·10^{13}) | 6.14·10^{10}(5.64·10^{10}) | 0.01(0.006) |
| PM10, %/(mg/m³)             | 7.12(11.962) | 7.56·10^{3}(1.15·10^{3}) | 0.06(5.52) | 7.58(4.78) |

Note: \(\delta_{\text{min}}\) – is the minimum dust particle size found in microphotographs, \(\mu m\); \(\delta_{\text{max}}\) – is the maximum dust particle size found in microphotographs, \(\mu m\); \(\delta_{\text{m}}\) – is the average dust particle size by weight, \(\mu m\); \(\lg \sigma\) – logarithmic standard deviation; \(R^2\) – correlation coefficient of experimental values with the integral function of the lognormal distribution.

**Figure 5.** Functions graphs of the lognormal distribution, where along the abscissa \(\lg \delta\) is indicated – the decimal logarithm of the dust particles size: 1 - bran; 2 - sunflower meal; 3 - wheat; 4 – corn

**Figure 6.** Density graphs of the lognormal distribution, where along the abscissa axis \(\lg \delta\) is indicated – the decimal logarithm of the dust particles size: 1 - bran; 2 - sunflower meal; 3 - wheat; 4 – corn

The graphs in Figure 5 and 6 are approximating curves of the experimental dispersion analysis results of dust, formed at the feed mills receiving centers, and are designed to quickly search dust cleaning supplies for air purification, the graphs in Figure 6 and the results in Table 2, where the curve extremum is average dust particle size.

It should also be noted that the dust generated during unloading of raw materials (especially wheat and corn dust) at the feed mills reception center may contain a certain amount of mineral impurities,
including silicon dioxide SiO$_2$, which may subsequently lead to occupational diseases - pneumoconiosis (Omidianidost 2015).

**Summary**

To determine the dispersed composition of dust, generated at the feed mills receiving center. It was acquired, that bran dust, sunflower meal, wheat and corn are coarse-particle, meaning, that the average size exceeds 10 μm, but it was noted that the PM2.5 and PM10 parameters for bran dust exceed the maximum permissible concentration in atmospheric air, and for dust of corn and wheat observed excess in terms of PM10. Values mean diameter and logarithmic standard deviation can be recommended for choosing cleaning supplies and to determine their effectiveness, and the approximating function itself when developing sequentially installed dust cleaning agents. For example, the efficiency of air purification from the studied dusts in a cyclone of the type TsN-11 (CN-11) will be, respectively, 89.6, 96.89 and 86.6%. The same data are the initial data when evaluating the effectiveness of the exhaust ventilation system at the feed mills receiving center.

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