ORIGINAL ARTICLE

Studying the Granulometric Composition of Rice Dust for Solving the Issues of Improving Environment Safety

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Abstract

Aim: The aim of this study is to determine the granulometric composition of the rice dust generated during processing rice powder at LLC "Southern Rice Company (SRC)," which is a strong allergen, to improve the environmental safety of production and working conditions. **Material and Methods:** Two samples of dust detained by a group cyclone and a bag filter-cyclone installed at LLC SRC were taken (station Kholmskaya, the Krasnodar region, Russia). To define the granulometric composition of dust for the fractions between 10 and 0.5 mm, the sieve method without rinsing with water was used, for fractions <0.5 mm, the sieve method with rinsing with water was used. In using the sieve method, the average sample for the analysis was taken using the quartering method. The weight of the sample was 50 g. **Results and Discussion:** The analysis of the content of rice dust fractions showed that a battery cyclone removes dust particles with the size between 10 and 1 mm. The fraction between 2 and 1 mm has the greatest percentage, equal to 39.4%. A bag filter-cyclone captures 90.42% of finer rice dust with a particle size <0.5 mm, out of which 65.34% are fine particles with size <0.1 mm. **Conclusion:** Introduction of a bag filter-cyclone at LLC "SRC" made it possible to increase the environmental safety of the production, to reduce overall emissions of pollutants into the atmosphere, and to improve the working conditions.

Key words: Rice dust, group cyclone, bag filter-cyclone, fractional composition, sieve method

INTRODUCTION

Technological processes of processing rice are accompanied by emission of rice dust. Studying disperse composition of the dust helps to assess its harmful effects on human health and choose appropriate dust separation equipment. Besides, disperse composition of the dust has a negative effect on the production environment and determines the nature and the conditions for dust propagation in the air. The most dangerous are fine particles, which penetrate into human lungs, causing various diseases.

Coarse dust settles at short distances from the source, while fine dust travels long distances with air currents, and settles much more slowly; particularly fine dust almost never settles. Thus, dispersion of dust particles in the air is determined by dust particle size distribution.[1]

In this regard, in Russia and several countries, the content of particles in the atmospheric air no larger than PM 2.5 and no larger than PM 10 is standardized, where digits indicate in microns (µm) particle size (aerodynamic diameter) of 2.5 µm and 10 µm, and the characters indicate particulate matters. On March 1, 2016, Governing Document GD 52.04.830-2015 "Mass concentration of particulate matters PM 10 and PM 2.5 in the ambient air was implemented in the Russian Federation. The gravimetric measuring method." Monitoring of fine particulate matters content in the atmosphere (PM 2.5

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and PM 10) is a prerequisite for maintaining air quality for protecting health. The gravimetric method of measurement for determining mass concentration of particulate matters is based on sampling air with the use of a certified sampling device with analytical filters, followed by weighing to determine the weight of the sample and calculating concentration in mg/m^3.

Paper[2] shows the distribution of grain dust particles in grain elevators. For a fabric dust collector, PM 10 (<10 μm) is 20% of the total amount of caught dust, and for a cyclone, it is 9%.

To assess the effect of rice husk dust on the health of workers at rice mills located in Allahabad (India), random groups of people 20-35, 35-50, and 50-65 years old were taken. India is the second largest rice producing and processing country after China. Clinical studies showed deviations from normal values of hemoglobin (decreased), lymphocytes (increased), monocytes (decreased), eosinophils (increased), platelets (decreased), etc.[3] It is known that reduction of, for example, hemoglobin, may result in constant fatigue, increased probability of infectious diseases, development of cardiomyopathy, enlarged liver, feet swelling, etc. Increased level of lymphocytes in the blood of adults results in infectious diseases and decreased the level of monocytes results in the development of tumors. Studying[4] health of workers at three rice plants located in the town of Bawla in the district of Ahmedabad (India) showed that 88.89% of the workers had annoying moist cough; 83.33% had chronic cough; 75% had chronic asthma; 66.67% had skin rash, and 66.67% had chest tightness. This study was performed to determine the microflora in the air of the rice plants working environment, since the respiratory system of workers is exposed to dust, bacteria, endotoxins, spores, chemicals, etc.

To determine the granulometric composition of rice dust for solving the problem of improving ecological safety, this paper is focused on two varieties of dust detained by a group cyclone and a bag filter-cyclone installed at the "Southern Rice Company (SRC)" LLC (station Kholmskaya, the Krasnodar region, Russia). The analyzed dust was obtained in processing raw rice of the Regul variety grown in the Krasnodar region of the Russian Federation.

Table 1: Amount of dust emitted in various areas of a rice mill

Location	Amount of dust, mg/m^3
Paddy pouring	18
Paddy shifting/sieve	9.8
Swaying/conveyers	8.5
Polishing	8.5
Bran filling	7.68
Rice sack	6.6
Total average	9.8

Related work

The paper[5] studies the amount of dust emitted at rice plants in various technological stages of rice processing [Table 1]. The greatest amount of dust in the air (18 mg/m^3) is detected during rice peeling in paddy-machines. Based on the calculated data and experimental studies, the authors have suggested changing the size of the cyclone exhaust pipe and adding three filtering units of various size to trap particles of rice dust smaller than 10 μm.

The authors of Varvarov *et al*.[6] have shown that efficiency of grain dust removal in battery cyclones is higher than that of other types of cyclones provided that they are correctly operated, and input speed of 18 m/s is maintained. Experimental studies were performed at grain processing enterprises and at grain elevators in the Voronezh region (Russian Federation) at various dust concentration at the entrance to the installations. The speed value at the input ranged between 10 m/s and 20 m/s. The experiments were performed with the use of a dust collecting tube external filtering in accordance with standard methods.

Rice dust particle size distribution is given in the research of C.B. Jr. Parnell, D.D. Jones, R.D. Rutherford and K.J. Goforth.[7] The mass average rice dust particle diameter was 21.75 μm. These studies (Texas) were performed to find the reason for explosions of various fractions of grain dust and to develop a cyclone, for assessing efficiency of which data about physical properties of dust are required. Figure 1 shows a histogram of the distribution of rice dust particles of <100 μm. The highest percentage of particles (12%) are those of rice dust between 16.0 and 20.2 μm.

Paper[8] studies fractional distribution of dust in various industrial premises of the mills [Figure 2] with typical location of the universalized process equipment. In the preparatory section, fine dust is present on the floor of seed hullers. The

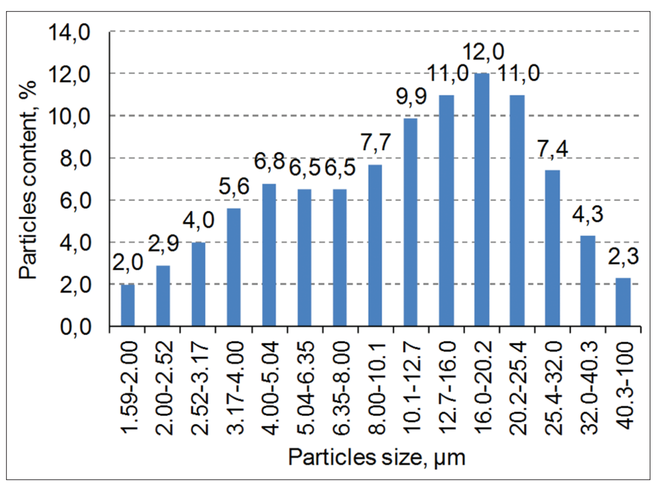

Figure 1: The histogram of distribution of rice dust particle with the size <100 μm

floor of grain separators is dominated by coarse dust. On the floor with stone separating machines, the total content of dust fractions smaller than 10 µm is over 63%, but given that the dust composition is dominated by mineral substances, it is especially unfavorable from the environmental point of view.

Proposed system

The "SRC" LLC produces elite brown rice of the native Regul variety, qualitative characteristics of which exceed similar parameters of the best-imported varieties. The characteristics of a rice processing enterprise as a source of air pollution and the measures for improving environmental safety of the raw rice milling process at, LLC SRC are reviewed in paper.[9,10] For cleaning, the dusty air coming from the aspiration and pneumatic networks, a battery cyclone plant is installed in the working tower of LLC SRC, the exhaust pipe of which is put into a setup box and into the air duct afterward. Next, the air is cleaned from large and medium particles and is supplied into the bag filter-cyclone. The battery cyclone is intended for purifying the air from coarse and medium dust, while bag filters are intended for capturing fine dust.

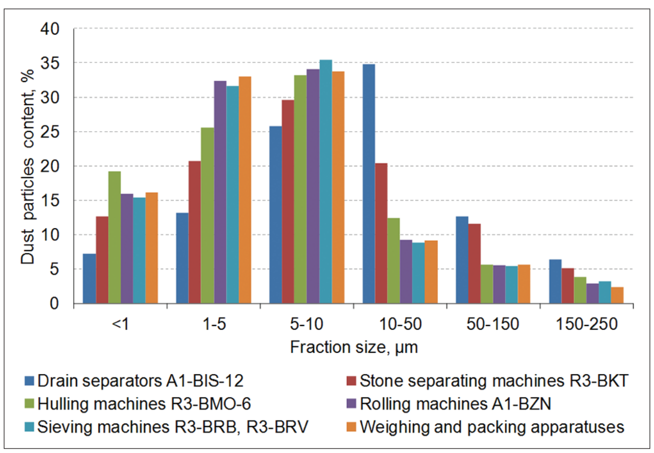

Figure 2: Fractional distribution of dust in the production areas of milling enterprises

Figure 3: Rice dust settles on the equipment

If the equipment that failed for technical reasons is operated, rice dust settles on equipment [Figure 3] and spreads across the shop floor [Figure 4], which can result in fire hazards and an explosion.

Explosive properties of rice dust are shown in Table 2.[11]

By its explosion danger and flammability, in Russia grain dust belongs to 2 class hazard (explosive dusts with the lower explosive limit at the concentration between 16 and 65 g/m^3).

This paper studies the textural (fractional) composition of rice dust sampled from a battery cyclone and a sleeve filtering cyclone. The granulometric composition of dust was determined according to GOST 12536-2014 (Russian Federation). The granulometric composition of dust is the percentage of primary (i.e., not associated into aggregates) particles of various size in fractions, expressed as a relation to their total weight. To define the granulometric composition of dust for the fractions between 10 and 0.5 mm, the sieve method without rinsing with water was used, and for fractions <0.5 mm, sieve method with rinsing with water was used. In using the sieve method, the average sample for the analysis was taken using the quartering method. The method of quartering involved spreading an even layer of the sample and dividing it into 4 pieces crosswise (quartering), of which two opposite parts were removed, and the remaining two parts were mixed again and divided into 4 parts. The weight of the remaining sample was 50 g. A standard set of sieves was used, composed of seven sieves: Round punched holes with the diameter of 10; 5; 2; and 1 mm, and three

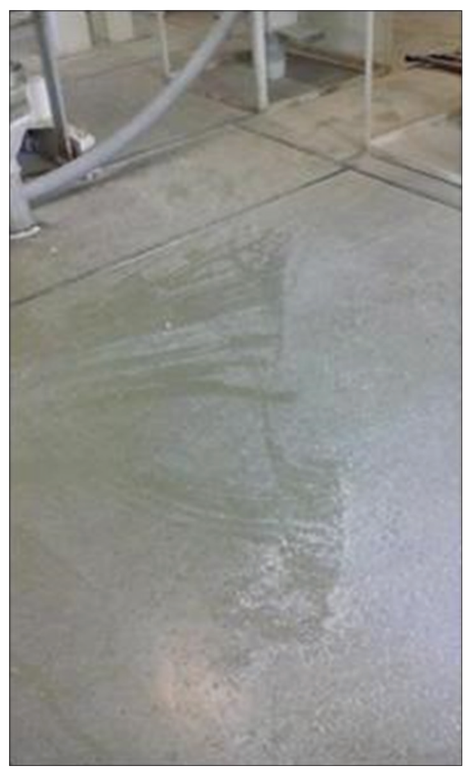

Figure 4: Rice dust settles on the shop floor (work area)

Table 2: Explosive properties of rice dust

Type of dust	Maximum pressure (kPa)[1]	Maximum rate of pressure rise (MPa/s)[2]	Ignition temperature		Maximum ignition enerdgy (J)[5]	Lower explosive limit (g/m^3)[6]
			Cloud (°C)[3]	Layer (°)[4]		
Rice	640	18.0	440	220	0.05	50

Source: U.S. Bureau of Mines 1961. This table is presented only to illustrate that grains are of varying volatility; it is not offered as a formula for calculations. 1 (kPa) is a symbol representing the maximum pressure rise, 2 (MPa/s) is a symbol representing the rate of pressure rise, 3 (°C) is a symbol for cloud where the auto-ignition in a combustible cloud is measured in degrees Celsius, 4 (°) is a symbol for layer where the layer ignition temperature is measured in degrees Celsius, 5 J is the symbol for the minimum ignition energy of a combustible mixture, 6 (g/m^3) is the symbol for the lower explosive limit of a given dust

Table 3: Fractional composition of rice dust from a battery cyclone and a bag filter-cyclone

Indicator	Sieve analysis						Sieve analysis with rinsing with water		
	Fraction (mm)								
	>10	10-5	5-2	2-1	1-0.5	<0.5	0.5-0.25	0.25-0.10	<0.1
Sample weight (g)						50			
Battery cyclone									
Fraction weight (g)	-	11.62	15.93	19.70	1.50	1.25	0.33	0.25	0.67
Fraction content (%)	-	23.24	31.86	39.40	3.00	2.50	0.66	0.50	1.24
Sleeve filtering cyclone									
Fraction weight (g)	-	-	-	0.21	4.58	45.21	4.56	7.98	32.67
Fraction content (%)	-	-	-	0.42	9.16	90.42	9.12	15.96	65.34

plain weaved sieves made of copper (brass) mesh with square holes with the size of 0.5, 0.25, and 0.1 mm. The sieves were mounted in the column from the tray in hole size ascending order. The top sieve was covered with a lid. The taken sample was transferred to the top sieve in the first set (hole diameter 10-0.5 mm), the lid was closed, and the dust was sieved until completely separated. Completeness of the sieving dust fractions was checked by shaking each sieve above a sheet of paper. If particles had fallen on the sheet, they were placed into the next sieve. When dust was separated into fractions by rinsing with water, the sample was placed into a porcelain mortar, wetted with water, and thoroughly triturated. The weighed quantity was transferred to a sieve with 0.5 mm hole diameter and elutriated under running water. Elutriation was continued until clear water escaped the sieve. The washed particles remaining on the sieve were quantitatively transferred into a preweighed porcelain cup, evaporated on a sand bath, and dried in an oven at (105 ± 5)°C. Then, it was sieved through a set of 0.5, 0.25, and 0.1 mm sieves. Similarly, completeness of dust fractions sieving at each sieve was checked with a sheet of paper. The content of each fraction *A*,%, was determined by the formula,

$$A=\frac{g_f}{g}\times 100$$

where, g_f - is the weight of this dust fraction, g; g is the weight of dust sample (50 g).

Fractional composition of rice dust is shown in Table 3.

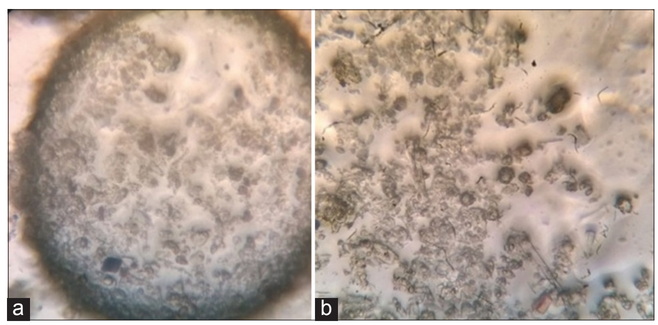

Figure 5: (a and b) Rice dust sampled from the bag filter-cyclone under the microscope (a) ×100 magnification, (b) ×1000 magnification

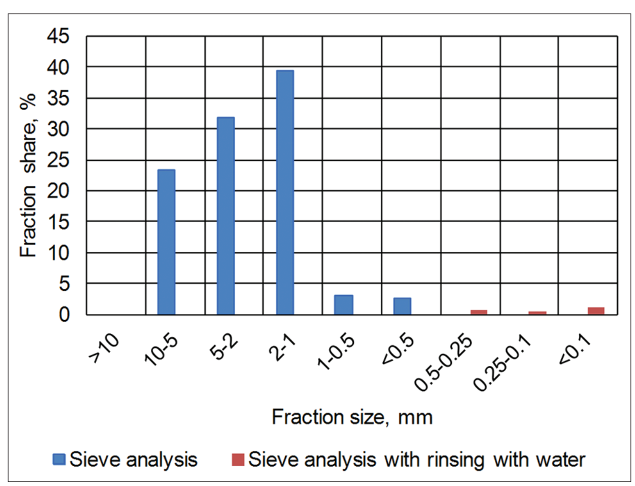

Figure 6: Fractional composition of rice dust taken from a battery cyclone

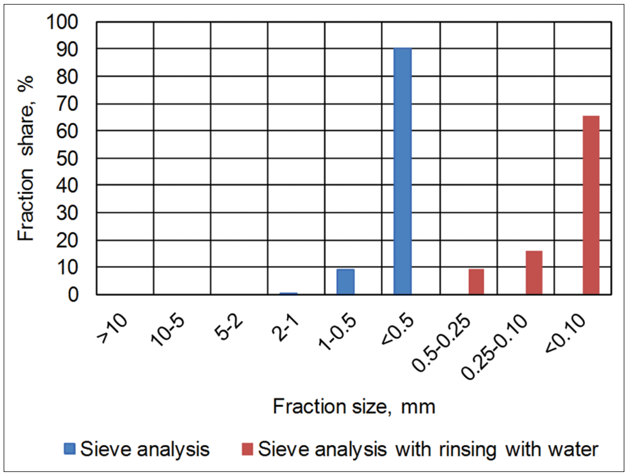

Figure 7: Fractional composition of rice dust taken from a bag filter-cyclone

Under the microscope, the fine dust sampled from the bag filter-cyclone looked like shown in Figure 5.

For the sake of clarity, Figures 6 and 7 show particle size (fractional) composition of the rice dust taken from the battery cyclone and a bag filter-cyclone in the form of histograms.

CONCLUSION

The analysis of the content of rice dust fractions shows that a battery cyclone efficiently removes dust particles with the size between 10 and 1 mm. The fraction between 2 and 1 mm has the greatest percentage, equal to 39.4%. A bag filter-cyclone captures 90.42% of finer rice dust with particle size <0.5 mm, out of which 65.34% are fine particles with size <0.1 mm. The introduction of a sleeve filtering cyclone at LLC "SRC" made it possible to increase the environmental safety of the production, and to reduce the total emissions of pollutants into the atmosphere.

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