Experimental studies to develop the measures for reducing dust emissions mass into the atmosphere from the sources of the aerated concrete structures shop

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Abstract: Most technological operations in the production of aerated concrete and building structures from it are accompanied by a significant amount of dust entering the atmospheric air. As a result, dust with a diverse composition enters the atmospheric air of the settlements in the territory of which the enterprises are located. The existing cleaning systems’ gears do not provide the necessary degree of dust emissions reduction in the atmosphere, exceeding the hygienic standards (the content in the air of settlements of particles with sizes less than 10 microns and 2.5 microns). The operation of CSF devices in cleaning systems has been shown to be effective in Russia and abroad. Increasing the CSF dust collectors’ efficiency can be ensured by organizing exhaust from the bin and when applying the flows with different dust contents to the lower and upper inlets.

Introduction
The aim of the study is to find the solutions to reduce the dust pollution level in urban air based on the development and study of the dust emission treatment systems’ layout schemes for the production of aerated concrete and aerated concrete building products using CSF. Improving the efficiency of the CSF dust collectors can be ensured by organizing exhaust from the bin and by applying the flows with different dust contents to the lower and upper inlets. For this purpose, the installation of additional CSF devices can be used to organize the gas-dust stream separation into the flows with a higher and lower concentration of dust particles. The objective is the development and study of the dust emission cleaning systems’ layout schemes for the production of aerated concrete and aerated concrete building products using CSF, with the organization of exhaust from the bin zone of dust collectors, and with the installation of an additional device on the recirculation duct [1-6].

Main part
The experimental studies to assess the dust emissions’ effect from the sources of the aerated concrete block production shop on the air quality in the urban environment were carried out at the existing enterprise in Rostov-on-Don.

In the workshop under study, the production process for the building blocks’ manufacture from autoclaved aerated concrete is carried out. The raw materials used are cement, lime, building gypsum, quartz sand, aluminum paste (powder). The production process consists of the following technological posts: chemical water treatment; reception department; grinding department; department for the preparation of aluminum suspension; mixing compartment; fill post; ripening post; cutting line;
autoclave department; product sharing and mold preparation; product packaging; finished goods warehouse; undercut crushing post [1-8].

In course of the experimental studies, the following were evaluated: actual dust emissions mass into the atmospheric air; fractional composition and concentration of dust contained in atmospheric air on the territory of the industrial site and on the sanitary protection zone border [9-10].

The actual mass of dust emissions was determined by the expression

\[ M = C L, \text{ g/s} \]  
(1)

where \( C \) - is the air pollutant concentration, mg/m\(^3\);
\( L \) - is the gas flow volume in the duct, m\(^3\)/s.

The volumetric flow rate of the gas stream in the gas duct

\[ L = v F, \text{ m}^3/\text{s} \]  
(2)

where \( v \) - is the average gas flow rate in the duct, m/s;
\( F \) - is the duct cross section, m\(^2\).

To determine the dust emission, the following instrumental measurements were carried out: duct diameters; duct pressure; air flow temperature; dust concentration in the duct. The measurements were carried out in the following sequence [14-17]:

1. Equipment preparation for the measurements (filters were weighed; aspirators and pressure gauges were checked; gas pressure tubes and sampling probes were prepared).
2. Checking the fittings on the ducts and the electricity availability at the measurement site.
3. Measuring the diameter of the duct to determine its cross-sectional area at the measurement site.
4. To determine the average flow rate and volumetric flow rate in the ducts, measure the dynamic flow pressure and determine the speed at points along the cross section of the ducts.
5. Air duct static pressure measurement.
6. Temperature and atmospheric air pressure measurement at the sampling site.
7. Sampling dust on filters at points along the cross-section of air ducts, calculating the sampling rate through an aspirator to comply with the conditions for sampling iso-kinetics. Temperature and flow rate measurement in the air ducts between dust sampling (to control the volumetric flow in the air duct and to comply with the conditions of sampling isokinetic).
8. Processing of measurement results, preparation for analysis of the selected samples, quantitative analysis of dust in the selected samples in the laboratory (drying and weighing filters, etc.). Dust concentration calculation in the ducts.
9. Determination of the dust emissions mass from the source. Calculation of measurement error.

Places for sampling and measurements of emission flow parameters were chosen so that these measurements provided the reliable results. The measuring section was selected in a straight section of the duct at a sufficient distance from the places where the direction of gas flow (elbow, bends, etc.) or the cross-sectional area of the duct changes. The measurements were carried out on the vertical sections of air ducts in which dust large fractions do not settle on the walls of the air ducts under the gravity action.

To measure the aerodynamic characteristics of the flow, Prandtl tubes and a differential digital pressure gauge DMC-01 / M were used. To measure the dust content, a standard set of dust extraction equipment NIIOGAZ was used (a sampling tube (probe) with a tip, an Migunov electric aspirator (model 822), AFA aerosol analytical filters placed in a closed or open allonge).

When conducting the measurements at the industrial site and at the border of the sanitary protection zone, a digital anemometer ISP-MG4 (developed and manufactured at the “Stroypribor” SCB) was used to measure wind speed (speed measuring range 0.1-30 m / s). To measure the temperature and relative humidity of the outdoor air at the sampling points, we used a digital electronic thermometer RSTO6412 / S412 (the temperature measurement range is – 50°C - 70°C; range of measurement of relative humidity of 1% -99%).
When assessing the dust fractional composition, a microscopic analysis technique was used to conduct the studies of fine dust particles PM10 and PM2.5 content [11-15]. Processing of the results of microscopic analysis was carried out in the DUST 1 particle image processing program. This software package was developed at the Federal State Budget Educational Establishment of Higher Vocational Education VolgGASU, received a certificate of the state registration.

For dust removal of air entering the exhaust system, dry cleaning is used, which is carried out in TsN-15 cyclones, because this is due to the production technology.

The results of the studies evaluating the power of dust emissions into the atmosphere are given in Table 1. The data obtained indicate that the dust cleaning systems used do not provide the necessary degree of dust removal from the emissions, as a result of which the mass of dust emitted into the atmospheric air exceeds the MPE standard.

**Table 1.** The experimental studies’ results to assess the power of dust emissions into the atmosphere

| Aspirated equipment | Exhaust system performance, [m³/h] | Dust concentration in the removed air, [g/m³] | Dust slip $\varepsilon_{\text{syst}}$, [%] | The mass of dust emitted into the atmosphere, M, [g/s] | M/EL |
|---------------------|-----------------------------------|-----------------------------------------------|------------------------------------------|-----------------------------------------------|------|
| Source conveyor     | 4750                              | 1.139, 0.16                                  | 14.1, 0.21                               | 1.3                                           |
| Scrap conveyor      | 4000                              | 4.21, 0.4                                    | 9.4, 0.44                                | 2.1                                           |
| Cutting line        | 6600                              | 1.16, 0.13                                   | 10.9, 0.24                               | 1.2                                           |
| Crushing post       | 7300                              | 1.23, 0.109                                  | 11.6, 0.11                               | 2.21                                          |

When developing the measures to reduce the dust emissions mass in the atmospheric air, an analysis of the dust size released from the technological equipment in the production of aerated concrete blocks was carried out. Some of the results are presented in Figure 1-4. Figure 1 shows microphotographs of dust particles taken in the aspiration system from the mixer.

**Figure 1.** Micrograph of dust particles taken in the aspiration system from the mixer: a - before cleaning in a cyclone; b - after cleaning in a cyclone
Figure 2 shows the integral passage functions for the dust particles coming from the aspiration system from the feed conveyor in the probabilistic logarithmic grid.

![Graph showing integral passage functions for dust particles](image)

**Figure 2.** Integral fractional distribution functions of the dust particles mass coming from the aspiration system from the conveyor of the source materials.

1, 2 - during lime transportation to the cyclone and after the cyclone, respectively; 3-5 - when transporting sand, gypsum stone, cement, respectively.

From the data obtained it follows that, after the existing dust removal system, the emissions, for example, lime dust come in, the particles of which have a median diameter of 5.5 microns and a particle size range of 1.5 to 15 microns.

Figure 3 shows the integral passage function for the dust particles emitted after cleaning into atmospheric air from the aspiration system serving the crushing station.

![Graph showing integral passage function for dust particles](image)
Figure 3. Integral passage function, for the dust particles emitted after cleaning into the atmospheric air from the aspiration system serving the crushing station

From the crushing station, dust particles with a median diameter of 12 μm and a size range from 1.8 to 18 μm come into the atmospheric air [17-19].

Figure 10 shows the results of assessing the fractional composition of dust contained in the air at the industrial site in the warm season. Fine dust particles less than 10 microns in size are present. The presented results indicate that the particles’ fraction values in summer fluctuate: for PM$_{10}$ from 12 % to 40 %; for PM$_{2.5}$ - from 0.3 % to 0.5 %. The median particle diameter is 11-15 microns [17-19]. The particles’ sizes vary from 1.5 to 20 microns [17-19].

Figure 4. The results of the fractional composition assessment of the dust contained in summer in atmospheric air on the industrial site territory
Figure 5. The results of the fractional composition assessment of the dust contained in summer in atmospheric air at the sanitary protection zone border

Figure 5 presents the results of the variance analysis of the dust particles contained in atmospheric air at the sanitary protection zone border. The data obtained also indicate the presence of particles with sizes less than 10 microns in the air. In this case, the fraction of the particles PM$_{10}$ accounts for 80% of the dust mass, the particles PM$_{2.5} - 0.5%$. Dust particles have a median diameter of 8.2 microns and size limits from 2 microns to 12 microns [17-20].

Summary
The conducted experimental studies showed the following results:
1. The test dust has a high dust-forming ability and is characterized by good flowability; the dust is polydisperse. The main fraction of the particles has a shape close to spherical, or elongated, oblong.
2. Dust enters the aspiration system, 25 to 100% mass of which falls on the particles with sizes up to 20 microns. The median diameter varies from 5.5 microns to 28 microns, the particles’ proportion with sizes less than 10 microns (PM$_{10}$) ranges from 6% to 65%.
3. The fact that the particle content PM$_{10}$ is found both in the emissions and in atmospheric air, can be used for assuming that the fractional efficiency of the dust collecting equipment used in dust cleaning systems is insufficient.
4. When using cyclones in dust removal plants in the aerated concrete and aerated concrete blocks’ production, an excess of particle content in atmospheric air may be noted as PM$_{10}$.

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