Analysis of the dust particles distribution and ventilation as a way to improve indoor air quality

E Yu Kozlovtsева¹, V N Azarov¹ and I V Stefanenko¹
¹Volgograd State Technical University, Lenin avenue, 28, Volgograd, 400005, Russia
E-mail: elenakozlovtsева@gmail.com

Abstract. The indoor air pollution is analyzed in the article. The subject of the research is the presence and composition of the dust particles taken into "traps" in the working space of the public building (Volgograd State Technical University, Volgograd, the Russian Federation). The research has established the range of sizes of the particulate matter (fractional composition) for the dust in the air of the working space in the form of integral curves for the mass distribution of particles with their diameters, it also provides the scheme of the air flows movement in the ventilation system of the room.

1. Introduction
At present, hygienic standards GN 2.16.2604-10 [1] have been enacted in Russia. Since June 21, 2010 the maximum permissible concentration (MPC) of pollutants in the atmospheric air of populated areas (mg/m³) has been established with respect to the particulate matter with the size of less than 10 μm (PM₁₀) and particles with the size of less than 2.5 μm (PM₂.₅). The influence of the particulate matter contained in the indoor air on the human health is much less studied. There are no restrictions on the amount of dust particles in offices, residential and educational facilities, i.e. non-industrial premises. However, according to the data of the US Environmental Protection Agency (the USA), the internal levels of pollutants can be higher in 2 - 5 times than in the open air [2]. The importance of the issue is emphasized by the fact, that people spend about 90% of the day indoor.

The quality of air in such premises is the key aspect to comfort, good health and high productivity in the workplace. It also affects the learning process of schoolchildren and students. But in the majority of the cases the problems are the modern equipment (operation of the office equipment), the use of finishing building materials in the construction and repair, and the use of chemicals for cleaning the premises [3-5]. Complaints from the office workers on health, an increase in the number of allergic reactions and diseases of respiratory system in children and adolescents, more frequent use of the term "Syndrome of sick buildings", which has become popular in the early 90's in Berlin, these all raises the need to examine the impact of uncertain risk factors in non-industrial workplaces [3-4, 6-9].

The particulate matter (abbr. PM), contained in the air of enclosed spaces, is a collection of a street dust, that comes into the building from industrial objects, household dust, road dust (functioning of the road-transport complex), as well as dust from the building, which is formed as a result of the operation of the office equipment, shoe soles abrasion, aging of finishing materials.

Let us consider in more detailed way the internal sources of dust formation, in particular the toner dust. The toner is used for printing in printers and copying machines. It is an organic powder of about 0.3-10 microns in average particle diameter, which contains carbon black as a black dye. The papers
dedicated to the subject of a negative impact of the toner particles on human health were published [10-12].

Taking into account the urgency of the aforementioned problems, the air environment of premises with the presence of office equipment has been considered in the present paper. In our research, the monitoring object is the working space with the following characteristics: height of the room - 2.7 m, materials for finishing - plastering (ceiling), wallpaper (walls), linoleum (floor), office equipment (personal computer, printer) and windows - double glazing with a small window. The research was conducted in the warm period of the year. Due to this fact, the working space was systematically ventilated and street dust came in.

The research is aimed to provide the calculated dependence of the dust particles distribution.

2. Material and experimental methods
The analysis of the fractional dust composition were conducted with the help of the optical method. This method is based on a microscopic analysis of the fine dust with the use of a microphotograph and a personal computer (PC) for the calculation of the fractional composition of dust in accordance with the size of dust particles using the software product - "SPOTEXPLORER V1.0" (Figure 1).

![Figure 1. Program interface "SPOTEXPLORER V1.0".](image)

On the basis of these data, the integral functions of the distribution of the mass of dust particles on the diameters were made analogically to the researchers [13-15]. The graphics have been drawn in probability and logarithmic scale.

3. Results and discussion
The processing of the experimental researches results made it possible to obtain the range of the fractional composition of the measured dust particles in the probability and logarithmic scale (1) (Figure 2).

The results of the research were recorded in Table 1.

On the basis of the results (Table 1), approximating graphs were made. The coefficient of the reliability of the approximation for these graphs: $0.44 < R^2 < 0.79$. It can be seen in the Figure 3 that the particle’s diameter decreases in contrast with the height of the room.
Figure 2. The range of integral curves for the mass particles distribution collected in the working space with diameters in the probability and logarithmic scale;

D (dₘ) — dust content, %, in the defined dispersive range set by the size (diameter) of dust particles dₘ.

Table 1. Characteristics of the fractional composition of dust particles distribution.

| Place of "traps" in the room | Height above floor level, m | Minimum particle diameter, dₘᵢₙ, μm | Average particle diameter, dₘₑₜₙ, μm | Maximum particle diameter, dₘᵕₓ, μm | Proportion of PM₂.₅, % | Proportion of PM₁₀, % |
|------------------------------|-----------------------------|-------------------------------------|--------------------------------------|-------------------------------------|------------------------|------------------------|
| The floor (near the PC system unit) | 0                           | 0.3                                 | 4.725                                | 21.78                               | 3                      | 99                     |
| The fan of the PC system unit     | 0.35                         | 0.3                                 | 5.475                                | 10.65                               | 0.5                    | 95                     |
| On the table, near the printer    | 0.8                          | 0.4                                 | 5.4                                  | 10.4                                | 1                      | 97                     |
| Shelf above monitor               | 1.4                          | 0.4                                 | 3.735                                | 7.07                                | 2                      | 99                     |
| Bookshelf (0.6 m to the ceiling)  | 2.1                          | 0.28                                | 5.18                                 | 10.08                               | 1                      | 88                     |
Figure 3. Graph of the correlation dependence of the maximum particle diameter ($D_{\text{max}}$) from the height (H) of the sampling points location. Nomenclature: 1,2,3 - distribution functions of particles selected for "traps" at different time periods. ■ - points corresponding to the function 1, ▲ - points corresponding to the function 2, ♦ - points corresponding to the function 3.

In those cases when it is necessary to simultaneously supply and remove dusty air from the premises, mechanical ventilation should be set up, or air should be supplied after mixing it with the room air. This use of indoor air is called recirculation. A possible scheme of air ducts with the designation of air flows according to the data [16] is shown in Figure 4.

Figure 4. Flow pattern of air flows in the ventilation system.
Nomenclature: EA - exhaust air, OgA – outgoing air, AS - supply air, SA - air supply, AH – air handling, AM – air-entrained mix, OA – outdoor air, RA - recirculation air (internal).

4. Conclusions
The presented data indicate that the measured dust particles are ranged from 0.28 to 21.78 μm. It confirms the presence of finely dispersed particulate matter, that can be in the state of Brownian motion for a long time and penetrate into the lungs; they are considered as the most dangerous for the human health.

The results of the research of the fractional composition of dust particles allowed us to estimate the fraction of PM$_{2.5}$ and PM$_{10}$. In the analyzed samples the proportion of PM$_{2.5}$ is ranged from 0.5 to 3%,
the proportion of PM$_{10}$ - from 88 to 99%. In addition, the correlation dependence of the distribution of the maximum diameter of particles is established with respect to the height of the location of the selected sample (Figure 3) - it decreases from the floor to ceiling. Thus, large particles, in view of their large diameter and, as a result of high speed of falling of the dust particles, immediately precipitate on the floor and surfaces close to it. However, the highly disperse dust do not settle even in calm air, it constantly moves in the airspace. At a height of 2.1 m from the floor level (the bookshelf) a larger diameter is observed than at a height of 1.4 m from the floor level (the shelf above the monitor), this can be explained by the ceiling, that is located close to the sampling point, and the presence of the old finishing materials - crumbling plaster; the room needs repair.

The conducted field studies allow us to estimate the particulate dust structure in the indoor air rooms depending on the height of the sample location. Dependences of distribution of the particles of maximum diameter to the location height (H) of places of sampling were received.

Estimation of the dust disperse structure reveals the real threat to public health, substantiates additional measures to reduce air pollution, makes adjustments to the ventilation and air purification systems in the rooms with constant stay of people. It can be used to identify characteristics of materials capable to adsorb dust particles and to optimize system of the wet cleaning of the rooms.

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