Influence of the Premises Dustiness Degree in an Educational Institution on the Choice of the Appropriate Air Filter Type

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Abstract. Students and teachers spend about 70% of the day in educational institutions. Therefore, recently in the world studies of the effect of air quality on human well-being and human performance have been conducted more often. The high content of suspended particles in the indoor air can lead to the development of allergies, and also serves as a factor of the transmission of respiratory viral infections. The purpose of this study was to determine the degree of dust in the indoor air in the classrooms. For this purpose, the photoelectric method of registration of aerosol particles and the Koch method were used. The results were evaluated according to two requirements for the amount of suspended particles in the air of the educational institution. Depending on the amount of suspended particles and their size, recommendations were given for filters to reduce the dust content of the internal air.

1. Introduction
Dustiness of air in educational institutions has a strong influence on the efficiency of a person and his mental activity [1-7]. Students and teachers spend from 3 to 9 hours in classrooms every day. It is estimated that about 30% of health problems associated with indoor air quality are the result of a high amount of suspended particles in the air [1].

The amount of suspended particles in the indoor air of a room is greatly influenced by the presence of ventilation (mechanical or natural through openings in the enclosing structure), the speed of air movement in the room, the amount of people and the degree of their work.

Most educational institutions do not have mechanical ventilation, but only a natural inflow of fresh air through openings in the enclosing structures. The number of students on the premises varies and is directly dependent on the time of classes and breaks. To determine whether the dust content of the internal air of classrooms satisfies normalized values and how to improve the indicators, this study was conducted.

2. Method of determining the dustiness of the room
Four rooms in the building of the university located in the Moscow city were taken into consideration. All premises are chosen different in their location, purpose, and number of people present in them with different lengths of teachers and students in them. Measurements were made on Monday from 10 to 11 a.m. In all the investigated rooms, only natural ventilation is provided through openings in the enclosing structures.
The first room (room No. 1) is a roomy hall on the 2nd floor with panoramic windows on one wall. During the period of break, there is an active movement of people. During classes, the flow of people decreases.

The second room (room No. 2) is an educational audience on the 6th floor, in which, before the dust measurement of the room, there were classes. The room is angular and the windows are located on two adjacent sides.

The third room (room No. 3) is a narrow hall on the 4th floor without external fences, which has many doors to classrooms.

The fourth room (room No. 4) is a classroom on the 5th floor with two outwalls with window. There were no educational classes in this audience for two days.

Two methods were used to determine the dustiness of the air in the room. The first was the photoelectric method of counting suspended particles in the air using a portable device Fluke 985 Airborne Particle Counter. The second is the sedimentation method (or the Koch method).

Measurements of suspended particles in the air with a Fluke 985 instrument were carried out in the center of each room 3 times with a 5 minutes intervals. Air volume for sampling taken 1.42 liters. After each measurement, a zero-count filter is used to exclude erroneous partings.

Structurally, the Fluke 985 counter is designed as a monoblock in which an optical system with a light source and photodetectors, a sampling system with an integrated pump, a microprocessor, and a display are arranged. A laser diode is used as a light source.

Determine the amount of dust in the air in the room using the Koch method, a nutrient solution (meat-and-peptone agar) was prepared and poured into petrie dishes. These cups were opened in each room for a time during which the Fluke 985 was also measured, that is, for 15 minutes. After that, the cups were placed in a thermostat and kept for two days at a temperature of +37 °C. The next step was to calculate the grown colonies and determine the amount of suspended particles in 1 m³ of room air using the Omelyansky formula:

\[
X = \frac{5 \cdot 100 \cdot 1000 \cdot A}{10 \cdot B \cdot t}
\]

where \( A \) - the number of colonies grown on agar in petrie dishes;
\( B \) - surface area of petrie dishes, cm²;
\( t \) - the time of deposition of particles on a petrie dish, min

3. Results of the study

According to the results of measurements of the amount of suspended particles in the air, the Fluke 985 instrument obtained values for six particle sizes in the range from 0.3 μm to 10 μm for all four rooms and they are presented in table 1.

| Number of investigated room | Size of suspended particles, microns |
|-----------------------------|-------------------------------------|
|                             | ≥0.3 | ≥0.5 | ≥1.0 | ≥2.0 | ≥5.0 | ≥10.0 |
| 1                           | 51543661 | 3836150 | 1185681 | 633333 | 111972 | 38028 |
| 2                           | 62992253 | 8784977 | 4192019 | 2534038 | 430986 | 73944 |
| 3                           | 48227464 | 2586385 | 550000 | 284038 | 61972 | 25822 |
| 4                           | 47580985 | 2231455 | 300235 | 98592 | 7512 | 2113 |

The results of airborne dustiness studies by the sedimentation method, as well as the percentage of discrepancies with the use of the Fluke 985 instrument are presented in table 2 for particles with a size greater than or equal to 10 microns. Moreover, the results of the Fluke 985 were calculated as an average of the sum of three measurements in each room.
Table 2. Concentration of particles ≥10.0 microns in 1 m³ of air, measured by Fluke 985 and Koch method

| Number of the investigated room | The number of particles in 1 m³ of air | % expenditure of results |
|---------------------------------|--------------------------------------|--------------------------|
|                                 | Device Fluke 985                    | the Koch method          |                          |
| 1                               | 38028                                | 35385                    | 6.9                     |
| 2                               | 73944                                | 67232                    | 9.1                     |
| 3                               | 61972                                | 21231                    | 17.8                    |
| 4                               | 2113                                 | 2123                     | 0.5                     |

Based on the data obtained, the total values of suspended particles ranging in size from 0.3 to 10 μm per 1 m³ of air measured by a Fluke 985 instrument for each room and each time interval were graphically presented in figure 1.

It is interesting to note that the average number of suspended particles ranging in size from 0.3 to 10 microns in each room according to the results of three measurements with the Fluke 985 device is most of all for room No. 2. Especially clearly the excess over other rooms in size of suspended particles of 10 microns, which is explained by the long stay (1.5 hours) of a large number of people in the room, compared with other options. That is why in number 4 the amount of particles with a size of 10 microns is the least.

Rooms No. 3 and No. 4 have approximately the same average number of suspended particles ranging in size from 0.3 to 10 microns due to the fact that measurements in the hall without external fencing were carried out during classes, so there were no people in the hall and some of the particles settled.

In room No. 1, a decrease in the number of suspended particles in the air in each time interval is traced, since measurements began in the middle of the break, when there was an active movement of students and ended when classes began and there were fewer people in the corridor.

The percentage of each fraction of suspended particles in 1 m³ of air from the total average value of all particles is the following: particle size ≥0.3 μm from 80 to 95%, particle size ≥0.5 μm from 4 to 11%, particle size ≥1 μm from 1 to 5%, particle size ≥2 μm from 0.5 to 4%. It is interesting to note that the percentage of each fraction of the total number of particles in 1 m³ of air in different rooms is about the same.

Figure 1. The total values of suspended particles ranging in size from 0.3 to 10 microns per 1 m³ of air, measured by the Fluke 985 device for each room and each time interval
The Russian norms and specifications currently have no requirements for the number of suspended particles in the indoor air of classrooms. The only requirements for GN 2.1.6.3492-17 [8] regulate the values of maximum allowable concentrations of suspended particles PM2.5 and PM10 in atmospheric air. This requirement we refer to the internal air, since the premises provide natural ventilation through the openings of enclosing structures. To assess the dust content of indoor air, it is necessary to convert the results of measurements obtained in the amount of suspended particles in 1 m\(^3\) of air to the concentration of particles in mg/m\(^3\). Recalculation is made according to the formula:

\[ C = N \cdot \rho \cdot \frac{4}{3} \cdot \pi \cdot R^3 \]  

(2)

where \(N\) – the number of suspended particles per 1 m\(^3\) of air of the size for which the conversion is made; 
\(\rho\) – is the particle density equal to 1.8 kg/m\(^3\); 
\(R\) – particle radius, m.

The results are presented in table 3.

In this case, the number of suspended particles according to the calculation does not satisfy the normalized value of the average daily maximum allowable concentration of particles in the air only for room No. 2. To reduce suspended particles in the air used air filters in the system of mechanical ventilation of air. Particles with a size of \(\geq 10\) μm can be lowered with F7 pocket filters, which trap suspended particles of more than 5 μm with an efficiency of 80-90%. Thus, using this filter, we achieve a decrease in the average daily particle size in the air to a normalized value.

There is also a rationing of the maximum allowable concentrations of suspended particles in the indoor air for nine grades of clean rooms [9]. In a number of studies, public buildings equate to ISO cleanliness grade 8. In this study, premises were also assigned an ISO purity grade 8 and table 4 presents the results for compliance with the requirements of indoor air for classrooms.

### Table 3. Average daily concentration of suspended particles in the air, mg/m\(^3\)

| Number of the investigated room | Suspended particles PM2.5 | Suspended particles PM10 |
|-------------------------------|--------------------------|-------------------------|
|                               | By calculation           | The normalized value of the average daily MAC | By calculation | The normalized value of the average daily MAC |
| 1                             | 0.008                    | 0.035                   | 0.057          | 0.060          |
| 2                             | 0.026                    | 0.035                   | 0.146          | 0.060          |
| 3                             | 0.004                    | 0.035                   | 0.036          | 0.060          |
| 4                             | 0.002                    | 0.035                   | 0.005          | 0.060          |

From table 4 we see that only room No. 4 meets the requirements for the maximum allowable concentration of particles in rooms of ISO cleanliness grade 8. For the rest of the premises it is necessary to provide measures to reduce the dustiness of the room air.

### Table 4. Concentrations of suspended particles in the air, particles/m\(^3\)

| Number of the investigated room | Suspended particle size \(\geq 0.5\) | Maximum allowable particle concentrations |
|--------------------------------|---------------------------------------|------------------------------------------|
| 1                              | 3836150                               | 3250000                                  |
| 2                              | 8784977                               | 3250000                                  |
| 3                              | 2586385                               | 3250000                                  |
| 4                              | 2231455                               | 3250000                                  |
Table 5. Concentrations of suspended particles in the air, particles/m³ - continued

| Number of the investigated room | By calculation | Maximum allowable particle concentrations |
|---------------------------------|----------------|--------------------------------------------|
|                                 | Suspended particle size ≥1.0 |                                            |
| 1                               | 1819014         | 832000                                    |
| 2                               | 6726056         | 832000                                    |
| 3                               | 834038          | 832000                                    |
| 4                               | 398826          | 832000                                    |
|                                 | Suspended particle size ≥5.0 |                                            |
| 1                               | 150000          | 29300                                     |
| 2                               | 504930          | 29300                                     |
| 3                               | 87793           | 29300                                     |
| 4                               | 9624            | 29300                                     |

For purification of indoor air in rooms of cleanliness grade 8, the ISO standard GOST R 56638-2015 [10] recommends the use of filters of class F7, F9 and E11. The F7 pocket filter can be used to trap suspended particles larger than 5 microns in size, and this filter is usually used as the first cleaning stage. As a second stage of air purification, high-performance pocket F9 fine filters are used, which trap particles larger than 1.0 microns in size. For rooms No. 1 and No. 2, it is necessary to apply a high-performance HEPA filter E11 to clean internal air from particles larger than 0.5 microns in size. The efficiency of this filter is more than 95%.

Thus, the simultaneous use of filters of class F7 and F9 in the ventilation system of room 3, and filters of class F7, F9 and E11 in the system of ventilation of rooms 1 and 2, we achieve purification of indoor air of rooms up to normalized limits for clean rooms of ISO grade 8.

4. Conclusions
Analysis of the dust content of the internal air of various rooms of educational institution showed that it is necessary to provide a mechanical ventilation system, since the natural ventilation system through non-density outdoor fencing does not provide the required cleanliness of the internal air. For more efficient air cleaning, use air filters of a cleaning class for different sizes of suspended particles. To reduce the dustiness of air in educational institutions, it is sufficient to use class F7, F9 and E11 filters in the ventilation system.

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