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Dust pollution in the sport facilities

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Abstract. The aim of this paper is to present the results of microclimatic research focused on the dust pollution in several buildings and different rooms used for sport activities at the University. The attention is paid mainly to the problems of dimensions of space, capacity and activity of sportsmen, and influence of space ventilation. In the frame of this research the concentration of air dust was measured by the exact instrument DustTRAK II Model 8530 aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured. Obtained results of measurements were evaluated and concentrations of different size of dust particles were analysed. Results of different indoor conditions were generalized. Based on the results of measurements practical recommendations for the design, use and ventilation of these types of buildings were summarised in the conclusions.

Key words: air, dust fractions, gyms, indoor environment, swimming pool, ventilation.

INTRODUCTION

Dust is one of the most common pollutants, which people face in everyday life and in their work activities. By dust we understand air pollution particles of matter that dispersed in the air create aerosols. Dust is characterized by a concentration, size and properties of dispersed particles. On all of those characteristics depends the influence on health. The harmful effect of dust on humans is very wide. Evaluation of dust depends on the origin, nature and size of the dust particles, on its concentration in the air, but also on the length and conditions of action, and on the human individual sensitivity to dust.

The attention to dust is paid in many research works, e.g. Skulberg et al. (2004), Bouillard et al. (2005), Mølhave (2008), Mølhave et al. (2009), Buchholz et al. (2011), Nõu & Viljasoo (2011), Brodka et al. (2012), Traumann et al. (2013), Traumann et al. (2014), Kic (2015). The methodology and the results of measurements correspond to the research topic, especially to factors that are specific to studied space. There are studied e.g. the impact of outdoor particulates transferred into the indoor space, the impact of processed and handled material, the influence of floor surface, the influence of sports equipment (climbing chalk), particles released from special plastic materials used indoor etc.

Particles of internal dust are generated primarily by internal surfaces and devices of buildings, textile materials used in the interior, sloughing skin cells from people, etc.; part of household dust comes from atmospheric dust outside. The problems of the dust in gym air were studied e.g. by Carignan et al. (2013), Alves et al. (2014), La Guardia & Hale (2015).

Over many years of research, it was found that the effect of solid dust particles on health depends mainly on their size. Particles bigger than 100 µm have relatively little importance for human health, because due to its considerable weight quickly settle. The size of dust particles is 1 to 100 µm, particles larger than 30 µm, are known as coarse dust in the environment and in normal conditions also quickly settle. In terms of human respiratory tract larger particles do not cause major problems, since they are recorded on the hairs in the nose and do not penetrate further into the airways (Hollerova, 2007).

Inhalable fraction of dust means a set of airborne dust particles that can be inhaled through the nose or mouth. Respirable fraction means the weight fraction of inhaled particles which penetrates into the respiratory tract where is no ciliated epithelium and in alveoli.

Particles smaller than 10 µm (Particulate matter PM_{10}) are of great biological importance because they can penetrate behind the larynx into the lower airways. Therefore these particles are called inhaled particles or thoracic particles. These particles can settle in the bronchial tubes ($PM_{2.5}$), or penetrate into the alveoli (PM_1) or to the blood (nanoparticles) and cause health problems (Hollerova, 2007).

The use of PM_4 is not as common as the previously mentioned PM. According to Boac et al. (2009) the American Conference of Governmental Industrial Hygienists has defined three particular mass fractions in relation to potential health effects: inhalable fraction (particulate matter (PM) with a median aerodynamic diameter of 100 µm that enters the airways region), thoracic fraction (PM with median aerodynamic diameter of 10 µm that deposits in the tracheobronchial regions), and respirable fraction (PM with a median aerodynamic diameter of 4 µm that enters in the gas exchange regions), herein referred to as PM_4.

Weschler et al. (2008) the particle concentration calculated from total airborne concentration and the concentration of airborne particles PM_4. According to the Standard of dust concentration in Japan for the protection of people´s health includes especially for the ambient air, the indoor air quality control and for health standard for office in construction site PM_{10}, and for the workplace assessment standard PM_4.

Ehrlich et al. (2013) focused his measurements on the crystalline silica in occupational health and recognised that most of those respirable particles are smaller than four microns (PM_4).

Fromme et al. (2007) evaluated indoor air quality and dust particle fractions (PM_{10} and $PM_{2.5}$) in 64 schools during the winter and summer. The winter concentrations $PM_{10} = 91.5$ µg m^{-3} and $PM_{2.5} = 19.8$ µg m^{-3} were significantly reduced in summer $PM_{10} = 64.9$ µg m^{-3} and $PM_{2.5} = 12.7$ µg m^{-3}. Herdorf et al. (2009) measured PM_{10} in classrooms with objective to study impact of cleaning. Intensified cleaning showed a significant decrease in all classrooms from 79 ± 22 µg m^{-3} to 64 ± 15 µg m^{-3}.

Problems of dust inside the houses and rooms are also as the dust can be source of house dust mites which are present indoors wherever humans live. Positive tests for dust mite allergies are extremely common among people with asthma. According to the WHO (2000) and Hurley et al. (2005) long-standing increased concentration of dust particles PM_{10} results in an increase in total mortality.

As the university students as well as the staff should be active not only in the study or research but also in the sport activities, it is important to know what the situation inside the sport facilities is. Due to the fact that during sport activities people breathe very intensively, the air inside the rooms should be very clean. The aim of this paper is to present results of microclimatic research focused on the dust pollution in several rooms used for physical education and sport activities at the Czech University of Life Sciences Prague.

MATERIALS AND METHODS

This research work and measurements of the actual values were carried out in buildings and rooms of Department of Physical Education at the Czech University of Life Sciences Prague. All rooms are situated in two buildings, three of them in the same building (two conventional gyms GA, GB and one fitness centre GC). The first gym GA has the following dimensions: floor area about 540 m^2, volume 4,320 m^3 and it is used mainly for different ball games. The second gym GB has the following dimensions: floor area about 216 m^2, volume 1,728 m^3 and it is used mainly for sports games, floor exercise, aerobics, table tennis, etc. The third gym GC has the following dimensions: floor area about 92 m^2, volume 240 m^3 and it is used as a fitness centre. The last building is swimming pool centre SP (pool is 25 m long), which has the following dimensions: floor area about 640 m^2, volume 4,018 m^3.

The dust measurements were carried out first when all rooms were empty, without students and without ventilation, several days without cleaning the floors. The same dust measurements were carried out during the normal function of rooms, with students and with standard ventilation. There were following number of persons during the measurement inside the rooms: GA 20 students play floorball, GB 27 students doing aerobic exercise, GC 18 students in fitness training, SP 20 students swim.

The total concentration of air dust was measured by special exact instrument Dust-Track aerosol monitor. After the installation of different impactors the PM_{10}, PM_4, $PM_{2.5}$, PM_1 size fractions of dust were also measured. The 90 data of dust concentration for total dust as well as of each fraction size in each room were collected, in several representative and available places, which can be used for measurement without technological problems. The position of measuring instrument was usually at 115 cm above the floor.

Measuring devices and equipment technology environment continues to improve and provide a larger volume and more accurate results. New studies are constantly providing fresh information, but there are still many uncertainties. Maybe, new and more precise ideas about the influence on the human health can be discovered.

Very helpful and also important is to know the details about the composition and size of dust particles from the point of view of technical equipment and technology of indoor environment. This is important among other things for the selection of appropriate filters, scheduling maintenance and cleaning, and overall management options how to reduce the dust inside the buildings.

There are the reasons why the measurements have been provided not only according to the prescribed normal national or international standards (e.g. PM_{10} and $PM_{2.5}$), but it was also measured the total dust concentration and particulate matter by all available impactors PM. Larger amounts of information allow to obtain more detailed information on the composition and percentage of size fractions of dust.

According to the Air Protection Act No. 201/2012 PM_{10} limit value in 24 hours is 50 µg m^{-3}, 1 year limit value is 40 µg m^{-3} and 1 year limit value $PM_{2.5}$ is 25 µg m^{-3}. The 90 data of dust concentration for total dust as well as of each fraction size in each room were collected. The obtained results of dust measurements were processed by Excel software and verified by statistical software Statistica 12 *(ANOVA* and *TUKEY HSD Test*). Different superscript letters (a, b, c) in common are significantly different from each other in the rows of the tables *(ANOVA; Tukey HSD Test;* $P \leq 0.05$*)*, e.g. if there are the same superscript letters in all the rows it means the differences between the values are not statistically significant at the significance level of *0.05*.

RESULTS AND DISCUSSION

Principal results of dust measurement are summarized and presented in the Tables 1, 2, 3 and Figs 1, 2. The measurements in the empty, but not ventilated rooms (Table 1) show us that total dust concentrations and also concentrations of all dust fractions was in all rooms higher than 0.050 mg m^{-3}, which is dangerous for the human health. The lowest concentration of dust was in the swimming pool, which can be explained by the large area of the water surface inside. The worst situation was in the area of large gym GA and fitness GC.

Table 1. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in the empty rooms without ventilation. Different superscript letters (a, b, c, d) are the sign of high significant difference (*ANOVA; Tukey HSD Test*; $P \leq 0.05$)

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD
GA	80 ± 3^{a}	79 ± 3^{a}	77 ± 1^{a}	75 ± 2^{a}	70 ± 2^{a}
GB	74 ± 2^{b}	74 ± 2^{b}	73 ± 1^{b}	72 ± 1^{b}	66 ± 1^{b}
GC	81 ± 5^{a}	80 ± 3^{a}	78 ± 2^{c}	76 ± 2^{a}	72 ± 4^{a}
SP	56 ± 2^{c}	56 ± 2^{c}	54 ± 2^{d}	53 ± 2^{c}	50 ± 2^{c}

SD – Standard deviation

Table 2. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in the rooms with students and with ventilation. Different letters (a, b, c) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; $P \leq 0.05$)

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD
GA	33 ± 7^{a}	29 ± 4^{a}	25 ± 1^{a}	23 ± 1^{a}	20 ± 1^{a}
GB	41 ± 13^{b}	32 ± 5^{b}	25 ± 1^{b}	25 ± 1^{b}	22 ± 1^{b}
GC	34 ± 8^{a}	$30 \pm 5^{a,b}$	25 ± 1^{b}	23 ± 1^{a}	21 ± 1^{c}
SP	25 ± 2^{c}	24 ± 1^{c}	24 ± 1^{c}	23 ± 1^{c}	$21 \pm 1^{a,c}$

SD – Standard deviation

The measurements carried out during the normal function of rooms, with students and with standard ventilation (Table 2), show us that the limit level 0.050 mg m^{-3} of the dust concentration has not been exceeded in any room. The worst situation was in the area of gym GB which was probably caused by the bigger number of sportsmen. The limit value $PM_{2.5}$ 25 µg m^{-3} was exceeded only in this gym. The lowest concentration of dust was again in the swimming pool.

From the Table 3 it is apparent a very significant effect of ventilation on dust reduction. It can be assumed that, the dust concentration in tested rooms with students will be higher than in the empty rooms. From the comparison in Table 3 is obvious that the intensive ventilation contrary significantly reduced dust levels.

Table 3. Reduction of dust concentration due to the ventilation

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	%	%	%	%	%
GA	41.25	36.71	32.47	30.67	28.57
GB	55.41	43.24	34.25	34.72	33.33
GC	41.98	37.5	32.05	30.26	29.17
SP	44.64	42.86	44.44	43.40	42.00

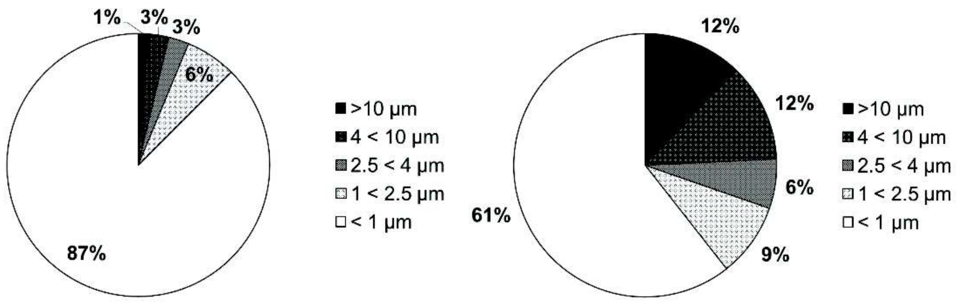

Figure 1. Percentage of dust fractions inside the empty gym GA without ventilation (left) and with students and ventilation (right).

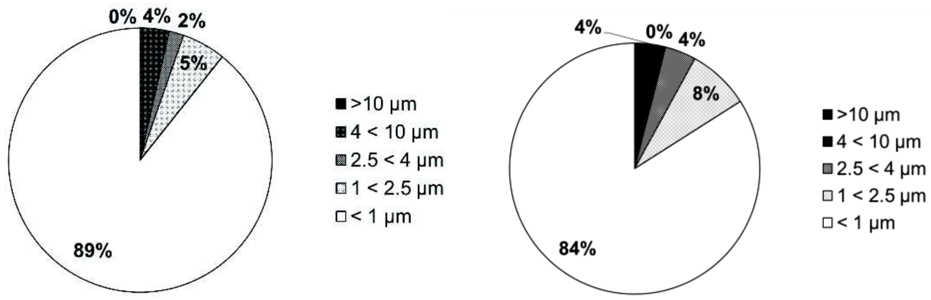

Figure 2. Percentage of dust fractions inside the empty swimming pool SP without ventilation (left) and with students and ventilation (right).

The Fig. 1 presents an example of the distribution of dust size of particles inside the gym GA without and with the ventilation. The main parts (87%) of the dust in the empty gym without ventilation are the particles smaller than 1 µm (size fraction PM_1). The air contains the biggest dust particles in very low percentage (1% of the particles bigger than 10 µm, and 3% of the particles smaller than 10 µm bigger than 4 µm). It is obvious that the small particles can move around freely in the air and the large particles settle down.

The use of the ventilated gym with students changed the percentage of dust fractions. There are 61% of the particles smaller than 1 µm and the percentage of big particles is higher (12% of the particles bigger than 10 µm, and 12% of the particles smaller than 10 µm bigger than 4 µm). This fact can be explained by the discharge of small particles due to the intensive ventilation. Similar situation is also in the other gyms.

The Fig. 2 presents the distribution of dust size of particles inside the swimming pool SP without and with the ventilation. Also in this case without ventilation the biggest part (89%) of the dust is created by particles smaller than 1 µm. During the intensive ventilation has been increased the percentage of the bigger dust particles, but not so much in comparison with the situation in the gyms. It is thanks to the generally lower concentration of the dust inside the building with swimming pool and also due to moisture and wet conditions which enable fixing the dust to the wet surfaces and humid air.

CONCLUSIONS

The results of measurements in the University sport facilities showed that:

- average concentrations of dust in all gyms as well as in the swimming pool without students and without ventilation was over the level 0.050 mg m^{-3},
- the biggest percentage of dust particles are small size particles PM_1,
- very big influence on the indoor air cleanness and reduction of air pollution by dust has the intensive ventilation, which can reduce the total dust concentration and therefore also the concentration of all dust particles, mainly the small size particles PM_1,
- intensive ventilation is more important if the room has small dimensions and number of sportsmen is high,
- the problem of dust is not so important for swimming pools, due to moisture conditions, humid air and intensive ventilation.

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