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IMPACT OF VENTILATION ON THE INDOOR PARTICULATE MATTER CONCENTRATIONS IN A SCHOOL

BY

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Abstract. Indoor air quality in schools is one of the main concerns for the health of children. Inside a classroom there are high levels of different pollutants concentrations along with high levels of particulate matter (PM). Many studies showed that PM can severely affect the health of children, especially those with asthma problems. In this article an experimental campaign was conducted in two identical classrooms as size, orientation and number of persons with the purpose to evaluate the PM concentration. The only difference is one classroom is ventilated with fresh air while the other one is not. With two GRIMM measurement equipment we have measured for two days the indoor levels. In fact, the ventilation system was found efficient especially for larger particles (PM10) of dust while for smaller ones (PM1) the results were similar. We have calculated a reduction of PM concentration of 10%,...,12% on the mean values. It is concluded that ventilation of schools has multiple benefits on the indoor air quality.

Keywords: indoor air quality; schools; ventilation systems.

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1. Introduction

Air quality indoors is very important for all buildings, especially in heavily polluted cities. Particulate matters are found in large quantities in indoor air as well as outdoor air. Many studies showed health risks if people are exposed for a long period of time, in indoor spaces without ventilation. Researchers studied the effects for short term as well as long term exposure and found lung diseases associated to particulate matter pollution (Pope *et al.*, 2002; Dockery *et al.*, 1993; Wallace *et al.*, 2006; Baulig *et al.*, 2009). Some researchers focused their research work on particle penetration through building cracks, showing the influence of the crack geometry on the mass transfer (Popescu & Limam, 2012; Olea *et al.*, 2008; Carrie *et al.*, 2002; Jeng *et al.*, 2006; Mosley *et al.*, 2001; Li *etal.*, 2003). Many simulation models can be found and used, offering detailed behavior of particle movement. CFD simulation id always used to study such a complex simulation.

Studies conducted in schools concerning particle matter and other pollutants are very interesting and showed correlations for mass transfer from outside to inside air (Dhalluin *et al.*, 2010). Ventilation proved to be very important to reduce the concentration of CO_2 found in schools, below the maximum acceptable limit of 1,000 ppm. In fact all indoor pollutants are decreasing if a ventilation system is used, or even natural ventilation is used (Poupard *et al.*, 2005; Blondeau *et* al., 2004).

Particulate matter (PM) is one of the criteria air pollutants which serves as an indicator of both indoor and outdoor air quality. PM encompasses many different chemical components and physical characteristics, many of which are potential contributors to adverse health effects by Szigeti (Szigeti *et al.*, 2017).

PM samples were collected at two indoor locations per school building during the education hours – one class as study case and one for initial parameters with no ventilation systems (2 consecutive days; 8,...,14 h per day, with and without ventilation system) in one sampling campaigns. Measurements were conducted with Grimm 11-E mini laser spectrometer, one of the best known devices worldwide. It is one of the most reliable and best technology and easiest data communication of this kind.

More particulate matter in the air can be a major problem for human health, that's why a good identification of the source is very important. High concentration outdoors mean an important concentration indoors combined with sources encountered inside the buildings (Vilcekova *et al.*, 2016).

Public concern over indoor air quality (IAQ) has increased dramatically in recent years, as hundreds of pollutants from various indoor and outdoor sources have been identified in indoor environments, depending on the operations and activities that occur within the environment (WHO, 1987). These air pollutants have been associated with adverse health effects that have significant socio-economic impact (Ganick *et al*., 1995). Particulate matter (PM) has well-known negative health effects on humans. Numerous studies have shown that exposure to atmospheric particulate matter (PM) is associated with adverse health impacts such as heart and respiratory diseases (Hassanvand *et al*., 2014).

Mean values showed that students stay inside the schools 6.64 hours each day, the whole year for 180 days or 1,200 h. That's the reason why the indoor air should influence the health and also intellectual capabilities of the occupants (MacNaughyon *et al*., 2017).

When students have access to a green environment around the schools, their intellectual performance can increase, less stress can be shown or better focus on the subjects taught.

Sports in schools showed a great importance for physical and also cognitive functions, in this way the students proved to be more creative, also having a better intellectual development (Rice *et al*., 2016).

On the contrary an indoor air quality which is not very good, can cause a risk of mortality or health problems, especially for respiratory system. Such air is always found in polluted urban areas having a negative impact on students (Gasana *et al*., 2012).

2. Method of Measurement

The air that is measured enters in the device on the inlet aerosol connection, then the particulate matter is numbered by the light scattering cell and also counted and classified as a function of its size.

The measuring principle is schematically shown in Fig. 2.

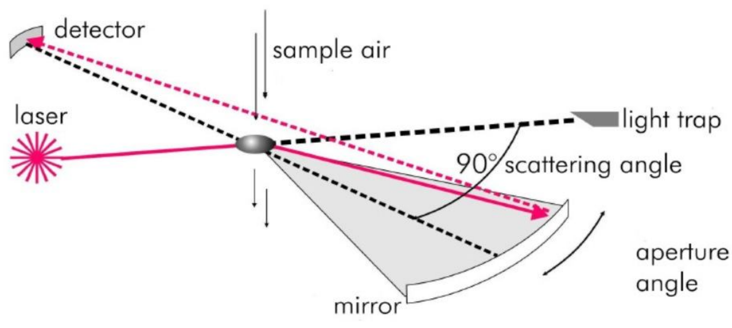

Fig. 1 – Measuring principle.

The Grimm laser aerosol spectrometers and dust monitors use a laser diode as light source. The wavelength is different within the model series in infrared range at 780 nm and in visible range at 655 nm. The laser diode can be operated in a so-called Multiplex Mode, *i.e.* the intensity of the laser beam is being modulated. This way particles can be detected over a very wide size range from 0.3 µm up to 20 µm respectively 0.25 µm up to 32 µm. The laser beam is focused to a flat elliptical strip by means of illumination optics. Inside the focus the laser beam lights a small measuring volume evenly and subsequently is being led into a light trap. The sample air is focused aerodynamically and then led as particle flow through the inner area of the measuring volume. When doing environmental measurements, the particle concentration of the sample air is normally so low, that statistically seen only one particle is in the measuring volume. Measuring at particle sources, technical particulate matters, or working places, very high particle concentrations can appear which require a previous dilution of the sample air. Due to the fact that the entire sampling volume of 1.2 liter/minute is analyzed, all Grimm aerosol spectrometers reach a very good counting statistic. The scattering light emitted by every particle is being detected by a second optics under a scattering angle of 90° and then directed onto a receiver diode via a wide-angle mirror. The signal of the detector will be classified into size channels after amplification subject to its intensity. Fig. 2 shows the assembly of the laser-measuring chamber. The sample air duct occurs perpendicular to the perspective into the measuring volume.

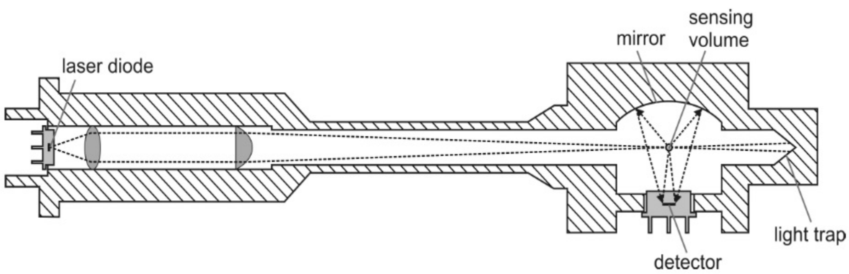

Fig. 2 – Laser measuring chamber.

The count rate results from the number of particles divided by volume flow rate. The particle size is proportional to the intensity of the detected scattering light signal whereas the scattering light intensity is also being influenced by the particles refractive index, particle shape, and orientation of the particle within the measuring volume. Positioning the detector into a 90° direction enables minimizing the influence of the aerosol particles´ refractive index for determining the particle size. The opening angle of the detector optics was chosen in a way so that an ambiguousness of the scattering light intensity due to MIE scattering undulations caused by monochromatic illumination is being compensated. Thus a distinct detection of the particle size in sufficient narrow size classes is possible. By detection of the particle concentration and particle size, the size distribution of the aerosol particles can be determined which in turn is the basis of the evaluation of the particle mass. Within measuring mode “particle mass” an additional size channel is arithmetically adjoined below the smallest size channel. For a precise and reproducible particle counting and particle sizing the accurate sampling volume of 1.2 liter/minute is absolutely fundamental. The sampling volume affects the conversion of the raw counts in the actual sampling volume in the selected unit, like liter or m^3 and secondly the particles speed in the optical chamber, which must be in the given tolerance range for a correct particle sizing.

3. Study Case Description

The experimental measurements were conducted in two identical classrooms from the college “Mihai Viteazul”, Bucharest, ROMANIA. The dimensions of the two analyzed rooms are identical (Floor surface of 54 m^2 with a height of 4.9 m and air volume of 299.88 m^3). These rooms have only one exterior walls facing West towards an inner courtyard. The building itself is not insulated but has very heavy walls (aprox. 1 m brick structure). The rooms are well air sealed due to three windows double pane type. One of the analyzed room is ventilated with a window fan introducing 450 m^3/h with the air jet flow towards the mid axis of the room. In each room during the test we had the same number of students (29 and 1 professor).

Fig. 3 − Measurement equipment photo and view of the non-ventilated classroom.

Continuous measurements of indoor and outdoor PM2.5 with a sampling interval of 1 min were performed. After each sampling, the impactors were cleaned and greased, the instrument was zeroed following the manufacturer's instructions.

a *b*

Fig. 4 − Mini Laser Aerosol Spectrometer (Mini-LAS) installed in a) classroom I-16 (no ventilation) b) classroom I-17 (with ventilation).

4. Experimental Measurements Results

In Figs. 5 and 6 it is presented the measured distribution of PM1, PM2,5 and PM10 in the ventilated room. We notice a maximum value of PM 10 of 131 µg/m^3 on the 4th of April and 141 µg/m^3 on the 5th of April, so close values for both days. For PM2,5 we have a maximum value of 22/26µg/m^3 and PM1 12/17 µg/m^3 on both days. So in the case of ventilated room the measured values are close in both days.

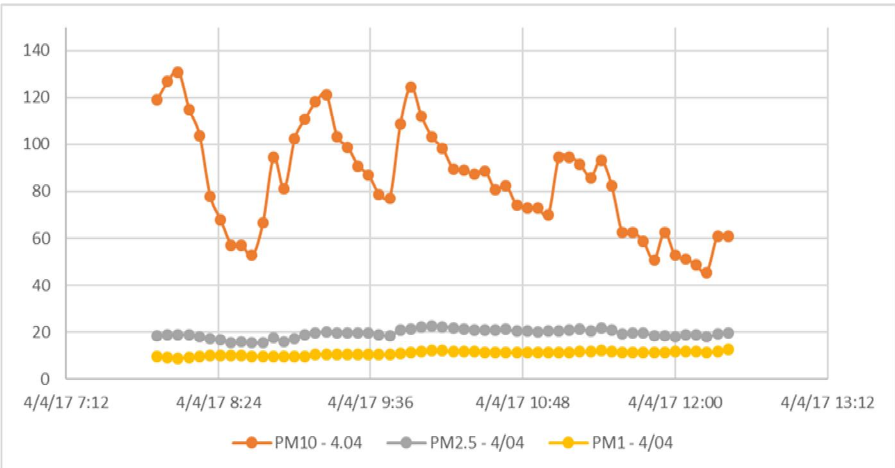

Fig. 5 – Measurements on the ventilated classroom on the 4th of April 2017, [µg/m^3].

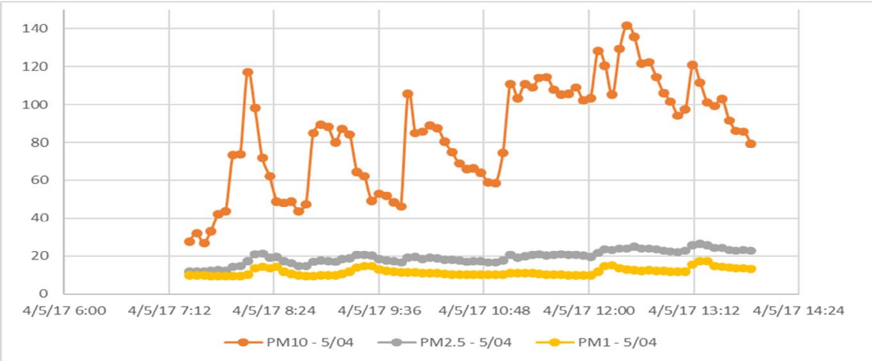

Fig. 6 – Measurements on the ventilated classroom on the 5th of April 2017, [µg/m^3].

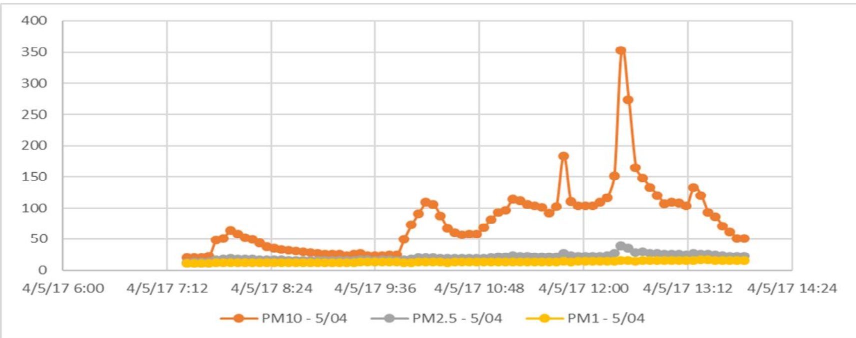

Fig. 7 – Measurements on the classroom without ventilation on the 4th of April 2017, [µg/m^3].

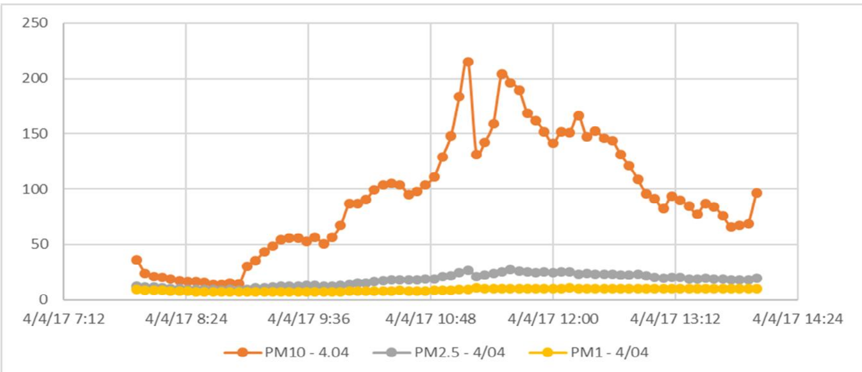

Fig. 8 – Measurements on the classroom without ventilation on the 5th of April 2017, [µg/m^3].

Comparing the values obtained for the ventilated and non-ventilated classroom we can compare the following maximum values (Table 1).

Table 1
Comparison Between Maximum Values of PM, [μg/m^3]

Day	With Ventilation			Without ventilation		
	PM 10	PM 2.5	PM 1	PM 10	PM 2.5	PM 1
4th April	131	22.5	12.4	215.2	27	10.6
5th April	141.8	26.5	17.1	353	38.8	16.6

In most cases we notice out of Table 1 that the ventilation can reduce the maximum values of particles, having even double values if there is no ventilation in the classroom. In the case of PM1 the values are very close, so there is no influence of the ventilation for these size of particles.

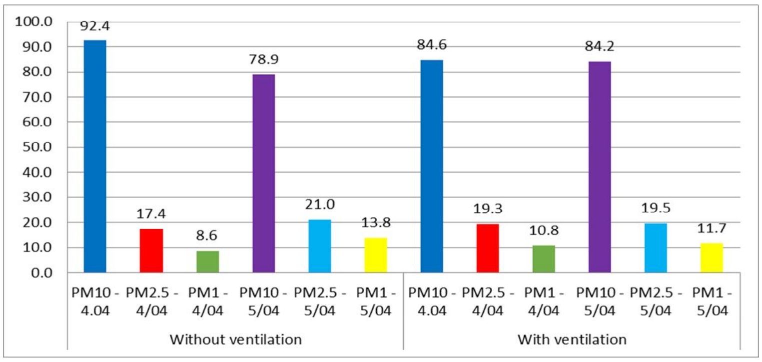

Fig. 9 – Mean values on the measured period from 4th and 5th of April 2017, [μg/m^3].

In Fig. 9 there are presented the mean values of particles for the whole measured period in both days. Just for small particles there is a reduction of concentration, which is not the case for PM 10, but it’s known that only small particles are dangerous for human health.

5. Conclusions

Comparing the two measured classrooms, one with mechanical ventilation and the other without any kind of ventilation we can conclude that the maximum values of particles are reduced during the period of measurement, even at half. The efficiency of the ventilation is mostly found for larger particles PM10 while for smaller PM1 the values were similar. A reduction of

10%,...,12% of the PM mean value concentrations were found. More detailed measurements are necessary especially on the assessment of outdoor PM values and introduction of air filters.

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IMPACTUL VENTILĂRII ASUPRA CONCENTRAȚIEI PARTICULELOR DE PRAF ÎNTR-O ȘCOALĂ

(Rezumat)

Calitatea aerului interior în şcoli este una dintre preocupările principale pentru sănătatea copiilor. În interiorul unei săli de clasă există niveluri ridicate de concentrații diferite de poluanți, împreună cu niveluri ridicate de particule de praf (PM). Multe studii au arătat că PM poate afecta grav starea de sănătate a copiilor, în special a celor cu probleme de astm. În acest articol a fost realizată o campanie experimentală în două săli de clasă identice ca dimensiune, orientare şi număr de persoane în scopul evaluării concentrației PM. Singura diferență este că o sală de clasă este ventilată cu aer proaspăt, în timp ce cealaltă nu este. Cu două echipamente de măsurare GRIMM am măsurat timp de două zile nivelurile de praf pe diferite clase. Sistemul de ventilație a fost găsit

eficient în special pentru particule mai mari (PM10) de praf, iar pentru cele mai mici (PM1) rezultatele au fost similare. Am calculat o reducere a concentrației PM de 10%,...,12% asupra valorilor medii. Se concluzionează că ventilarea şcolilor are avantaje multiple asupra calității aerului din interior.