

Particulate matter and airborne fungi concentrations in schools in Athens

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Abstract Indoor Air Quality degradation is of exceptional concern due to the potential adverse effects indoor air pollutants have on human's health. Students are a susceptible group of people, who spend a lot of their time within classrooms. The purpose of this study is to investigate the concentration levels of particulate matter (PM) and total airborne fungi, in school classrooms. Further objective is to examine possible correlations between PM₁₀, PM_{2.5}, PM₁, ultrafine particles (UFPs, diameter < 100 nm), and airborne fungi. The measurements were performed using fully automated instrumentation. The results indicate that a lot of PM₁₀ concentrations exceeded the proposed daily limit of 50 µg/m³. Also, in some cases the concentration of the total airborne fungi indoors, exceeded their concentration outdoors. There is evidence that certain correlations exist between PM and airborne fungi.

1 Introduction

In the recent years there has been a growing interest among the scientific community on the study of Indoor Air Quality (IAQ) as people spend approximately 90% of their time in indoor environments (EPA 1995a). People are largely exposed to indoor air pollutants for which there is evidence that cause adverse health effects when exceeding certain concentration thresholds. Exposures on indoor air pollutants such as UFP are linked with health effects such as asthma symptoms, allergies, respiratory and cardiovascular diseases (Pope and Dockery 2006). Airborne fungi concentrations are also related to several health problems such as irritations, infections and allergies (Pongracic et al. 2010). However, there is limited number

of studies in the literature concerning simultaneous measurements of PM and airborne fungi.

Children are more susceptible compared to adults due to the greater air inhaled in proportion to their body weight (EPA 1995b). Students in particular spend a considerable amount of their day time in classrooms (> 6 h per day) (Silvers et al. 1994). Degraded IAQ in classrooms impacts students' performance, attendance and comfort (EPA 1995b). Thus, the quality of air inside school classrooms is of primary concern.

The present study (i) measures simultaneously concentrations of both PM and total airborne fungi in classrooms of two schools, in Athens (ii) characterizes classrooms' indoor environments based on the proposed concentrations limit values by international certification bodies and (iii) examines possible correlations between PM of different aerodynamic diameters and airborne fungi.

2 Measurement methodology and instrumentation

Two high schools from contiguous areas outside the city center of Athens were selected in order to perform the experimental campaign. The first is placed in the Kaesariani (K) urban area away from major highway and is close to a park. The second school is in the Ymittos (Y) urban area where the traffic in the adjoining streets is moderate. The measurements started in January 2011 lasted until May 2011 and were conducted once a week fortnightly in each school. Air sample was collected from eight sampling sites K1 to K8 and Y1 to Y8 for each of the two schools (K and Y respectively); one was the outdoor environment and the other seven were in classrooms as well as teachers' office. Certain classrooms were occupied by students during sampling.

Measurements of PM₁₀, PM_{2.5}, and PM₁ in units of $\mu\text{g}/\text{m}^3$ were performed using the OSIRIS airborne particulate monitor (Turnkey Instruments Ltd). UFPs (<100nm in diameter) were measured using PTRAK (TSI, model 8525) in units of particles/cm³. The sampling apparatus were placed at 0.8 m height above the floor and were synchronized to monitor with a sampling step of 1 second. The duration of each measurement per position was 10 min.

For the recovery of airborne fungi a Burkard (Burkard Manufacturing Co. Ltd. Hertfordshire, UK) portable air sampler for agar plates was used. Three plates with Malt Agar were exposed consecutively in each sampling site for 3 min/plate and then incubated for 2 weeks. The colony count was corrected and expressed as colony forming units per cubic meter CFU/m³.

The statistical analysis was performed using SPSS 18 statistical software package as well as data analysis Microsoft Excel 2007. Average values and distributions of the measured parameters are characterized. Spearman's and Pearson correlation coefficients were calculated amongst different pollutants in order to understand the association between the measured variables. In the statistical anal-

ysis that follows, the average value of each 10 min measurement was taken into account.

3 Results

Fig. 1 left and right indicates the variation in time of PM_{10} concentrations at the two schools. Y-axis shows the average concentration per measurement, per sampling site, and X-axis shows the measurement dates. Intense fluctuations appear in some cases especially at school K (Fig. 1 left K3, st.dev. =46), whereas in school Y the variations are smoother (Fig. 1 right Y3, st.dev. =32). The monitored classrooms were naturally ventilated and the windows were kept closed during the sampling time. Outdoor fresh air did not enter the classrooms so as to meet ventilation requirements and to remove odors and contaminants. Furthermore the increased concentrations for certain dates are possibly linked to the presence of a large number of students occupying the classrooms before or during the measurement. This could be attributed to the fact that the physical activity and presence of students may result in the resuspension of coarse particles and therefore affect their concentrations (Guo et al. 2010). However, there were cases with high concentrations but without students being present prior or during the measurement (e.g. Fig. 1 left K3, March 3rd). Outdoor peak values at site K8 (17th and 31st of March) are due to the high relative humidity values as precipitation was observed on certain days. In addition, in these dates strong smell of smoke was detected which have also affected the concentrations. As for school Y, measurements do not fluctuate a lot (Fig. 1 right). The exceptional peak of PM_{10} concentrations on the 23rd of March of Classroom Y3 (Fig. 1 right) is due to the fact that this classroom was fully occupied by students that day right before the measurement, whose presence may have influenced the concentrations. It should be noted that this classroom was empty right before the rest of the measurement dates.

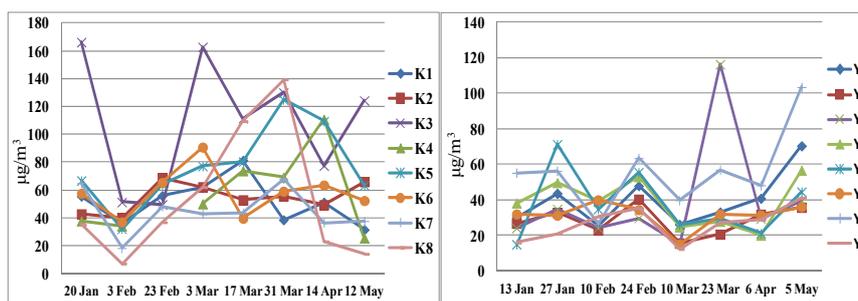


Fig. 1. PM_{10} concentration variation of school K (left) and of school Y (right).

The percentages of the total average PM_{10} and $PM_{2.5}$ values that exceed the WHO recommended 24-h limit value of $50 \mu\text{g}/\text{m}^3$ and $25 \mu\text{g}/\text{m}^3$ for school K are 60% and 5% respectively and for school Y are 17% and zero respectively.

The total concentration of the viable airborne fungi in the classrooms in each one of the schools, in several samplings is remarkably higher than that detected outdoors and this is an indication for the presence of amplification sources indoors. The mean concentration of total fungi in the seven locations sampled indoors is presented versus the concentration outdoors, for the two schools (Fig. 2).

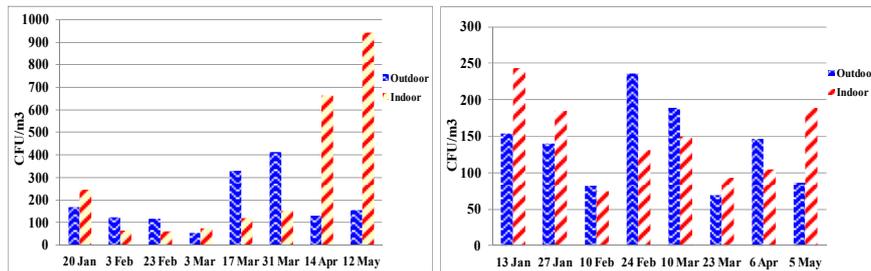


Fig. 2. Concentration of airborne fungi indoor vs outdoor in school K (left) and in school Y (right).

There is a spatio-temporal distribution in the concentration of fungi in the indoor air. The fungal load is presented in logarithmic scale (Fig. 3 left and right) in order to accommodate outliers. The concentration of fungi indoors ranged 28-548 CFU/m^3 excluding 4 extreme peaks in school K (Fig. 3 left) and 28-402 CFU/m^3 excluding 1 extreme peak in school Y (Fig. 3 right). There is not a universally acceptable threshold value limit for fungal concentration in relation to health impacts. It depends on several factors and mostly on the sensitivity of individuals.

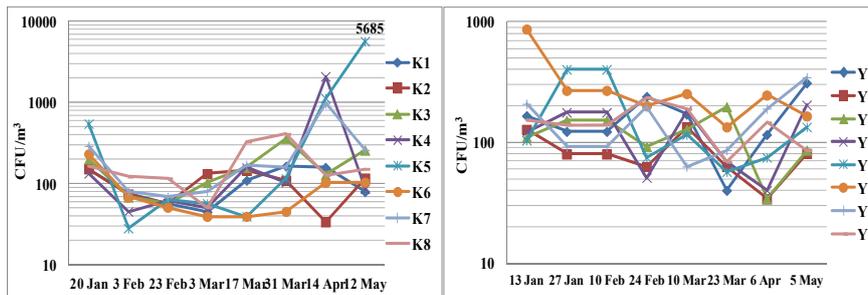


Fig. 3. Fluctuation of airborne fungi in school K (left) and in school Y (right).

Fig. 4 presents the distribution of the total indoor average concentrations of UFP for the two schools in box plots. The centre line of the box is the median; the outer lines of the box represent 25th and 75th percentile and the dotted values are outliers. It can be seen that UFP concentrations in school Y are greater than the

corresponding ones of school K and also present a stronger dispersion around the mean value. Vehicular emissions from the adjoining streets could have influenced the indoor concentrations of Y school. This is not consistent with the findings for school K which seemed to be mostly charged by larger particles.

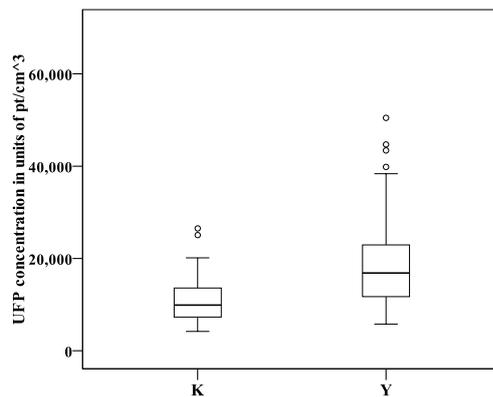


Fig. 4. UFP concentrations in particles per cubic centimeter for the two schools (K and Y).

As expected, from the statistical analysis that was performed it was found that PM_{10} are significantly correlated to $PM_{2.5}$ for both of the schools (Pearson correlation coefficient was approx. 0.7 at the 0.01 level for both schools). Thus, is in agreement with the findings of other research groups (Gaidajis and Angelakoglou 2009). As of the correlation between airborne fungi and PM, the statistical analysis shows that airborne fungi positively correlated to UFP for both schools. However, the correlations were weak as the correlation coefficients lie below 0.5 (0.310 and 0.356 at the 0.05 and 0.01 levels for schools K and Y respectively). It was found that PM_{10} concentrations correlated to the total fungi only in school Y (Spearman's correlation coefficient equal to 0.268 at the 0.05 level).

4 Concluding remarks

A great percentage of the PM_{10} measurements exceeded the recommended limit values especially in school K. School K is rather surcharged from coarse particles compared to Y school. However, school Y had increased concentrations of particles in the ultrafine range. PM concentrations increased with the presence of students and smoke and were influenced by outdoor vehicle emissions. Some correlation coefficients found to be statistically significant; however, there could not be found a generalized correlation pattern for both schools. Further research should be made on the simultaneous measurements of PM and airborne fungi for longer

measurement periods in order to develop a model for predicting the levels and interrelationships between PM and total airborne fungi.

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