Indoor air quality in two different office buildings—Part 2: Indoor and outdoor airborne particulate levels and air filtration

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ABSTRACT

The study has been carried out in two different French buildings. The main objective of the study was to know more about office buildings' indoor air quality as well as HVAC installation working over a long period (1 year). A lot of data are available but this paper focuses on the relationship between air filtration of the air handling units and indoor airborne particulate levels measured both in the offices and within the ducts of the air handling systems (outdoor air, blown air). The results of the study show how the fractional efficiency of the filters has changed along time. The air blown in the offices by the air handling systems is well filtered and reduces significantly the amount of particulates entering the buildings. The need of good air filtration for better indoor air quality has been shown.

INDEX TERMS

Indoor air quality; HVAC; Air filters; Particles; Air biocontamination

INTRODUCTION

People breathe approximately 15 000 l of air each day and spend more or less 80% of their time in indoor spaces. So, quality of indoor air is of major importance regarding health and comfort of people and there is naturally an increase of the need of 'good' indoor air quality. The aim of this study is to know more about how the HVAC installations work over a long period, to obtain data on HVAC installation working, to obtain data on indoor air quality and to record how it changes along a long period, and to develop test procedure for indoor air quality measurements.

METHODS

The study has been carried out between July 2001 and June 2002 in one office building located in downtown Lyon (called building 1) and between September 2001 and August 2002 in an other office building located in the suburbs of Paris (called building 2). Offices of the buildings are ventilated with a mixture of fresh air (outdoor) and recycled air. Air comes from an air handling system (located on the roof of the building) and is distributed in the offices through fan coil units (building 1) or through plenums and diffusion units (building 2). In building 1, air filtration of the air handling unit includes F6 class (EN 779) bag filters and F7 compact filters mounted in series while in building 2 G3 panel filters are used in series with F7 bag filters. Filters have been changed just before the measurements have begun. Windows of building 1 are non-opening and those of building 2 can be opened. Air is sucked out of the buildings through devices located in the corridors.

One-day continuous measurements have been carried out each month during a 1-year period. Indoor air quality in the offices is characterized by temperature and relative humidity

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of air, dust concentration (total), air biocontamination (bacteria and fungi) and gas concentration (CO_2, CO, NO_x, VOCs). Airflow rates distributed within the offices have been measured too. Airflow rates (outdoor air, blown air and returned air) of the HVAC installation have been measured and characterized with air temperature and relative humidity, dust concentration (total), air biocontamination (bacteria and fungi) and CO_2 concentration. Air filters have been characterized in the field (EUROVENT 4/10, 1996) and in laboratory (EUROVENT 4/9, 1997). For filters laboratory measurements (building 1 only), one filter of each rank is removed out of the air handling unit and installed again after measurements have been done. This paper focuses on indoor and outdoor airborne particulate and air filtration while more details about the method as well as other data obtained during the study—temperature and humidity of air, gas (CO_2, CO, NO_x, VOCs) concentrations, etc.—are presented in the first part of the paper (Ribot *et al.*, 2003).

RESULTS

The airflow rate blown by the air handling systems has remained more or less constant according to time, as can be seen in Figure 1. No significant changes have been recorded on airflow rate according to time. Twenty-four filters are used in parallel in the air handling system of building 1 while eight filters are used in the one of building 2. That means that the average airflow rate per filter is around 3000 m³/h for building 1 and around 2500 m³/h for building 2.

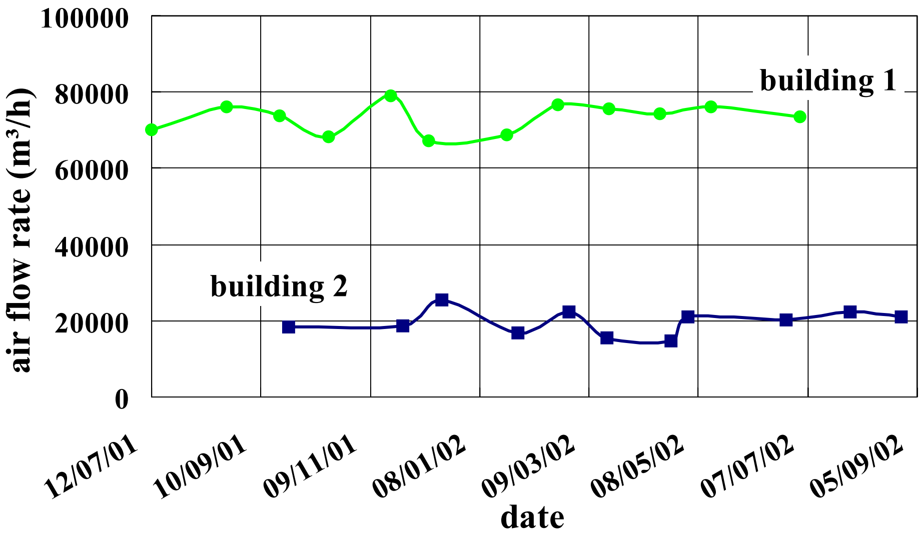

Figure 1 The airflow rate blown by the air handling systems, according to time.

The filtration efficiency of the air handling system of building 1 is shown in Figure 2a while the one of building 2 is shown in Figure 2b. For both air handling systems the initial efficiency does agree well according to the class of the filters that are used. In building 1 the efficiency has increased continuously during 8 months then started to decrease rapidly. It has been shown in laboratory (Ginestet et al., 2002) that the efficiency of the bag filters has remained more or less constant (very slight increase of the efficiency) while one of the compact filters has increased continuously during 8 months then started to decrease rapidly (it has been observed that some damages of these filters appear after 1 year of use). So, trend for air handling system of building 1 is mainly influenced by the behaviour of the compact filters. For the air handling system of building 2, the filtration efficiency has remained more or less constant during the period of the study.

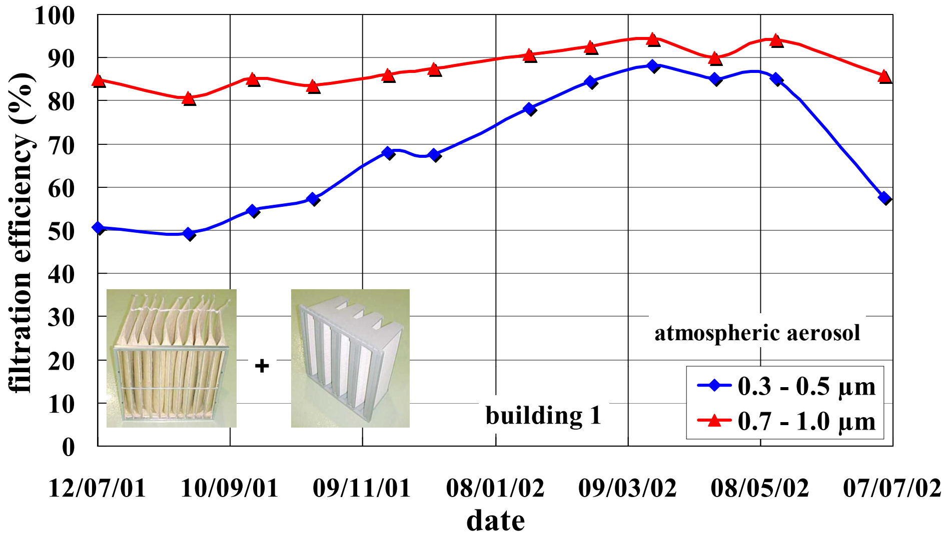

Figure 2a The filtration efficiency according to time (building 1).

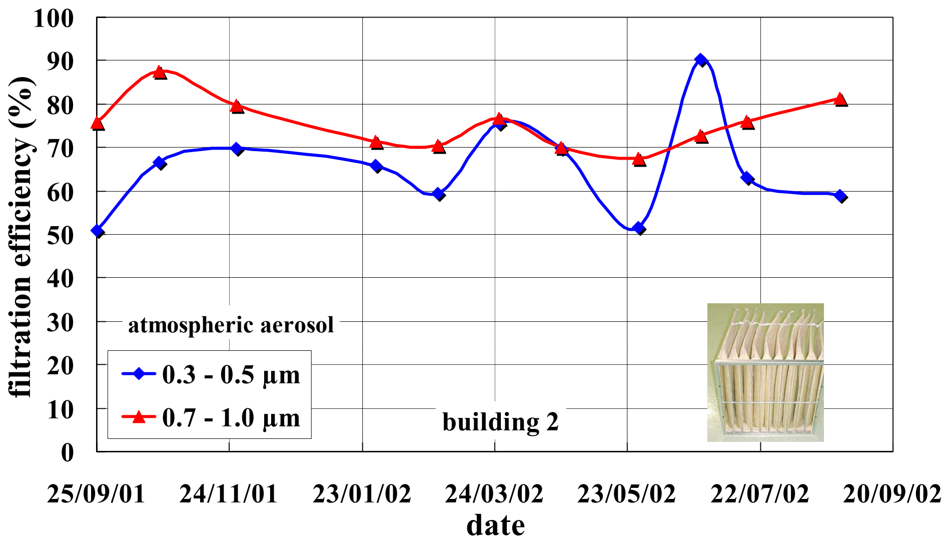

Figure 2b The filtration efficiency according to time (building 2).

In Figures 3(a) and 3(b), we have reported the values of dust concentrations measured outdoors, in the air blown by the air handling systems and in the offices. These values confirm that the filtration efficiency of the air handling systems is high (concentration in blown air is much smaller than the one in outdoor air) and that the use of the chosen filters can significantly reduce the amount of particles blown within the buildings compared to the amount of particles outdoors. There are no significant differences between outdoor dust concentrations measured both in Lyon and in Paris. The indoor concentrations are generally smaller than outdoors but there is no relationship between indoors and outdoors concentrations. Finally, it can be observed that the indoor dust concentration is low, generally less than 30 µg/m³.

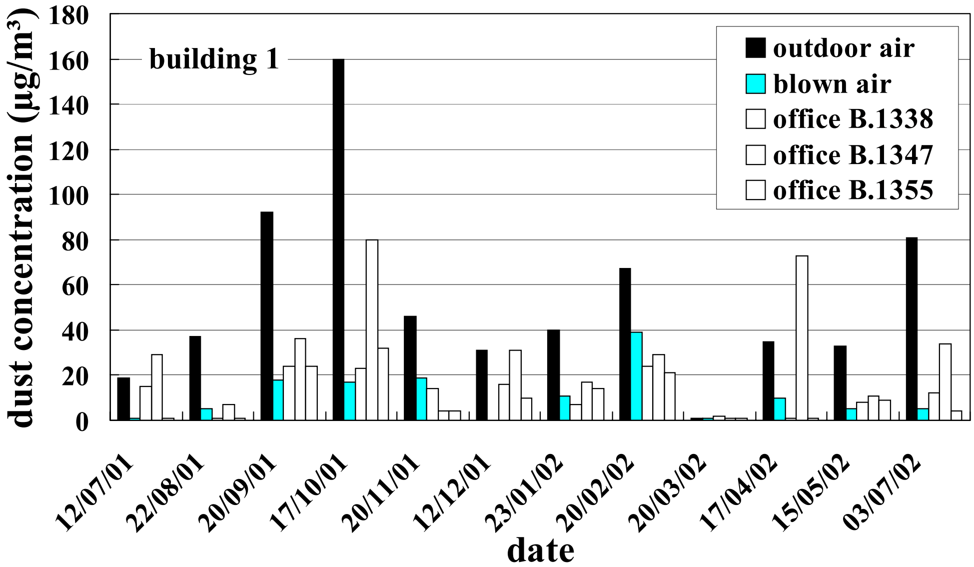

Figure 3a The dust concentration according to time (building 1).

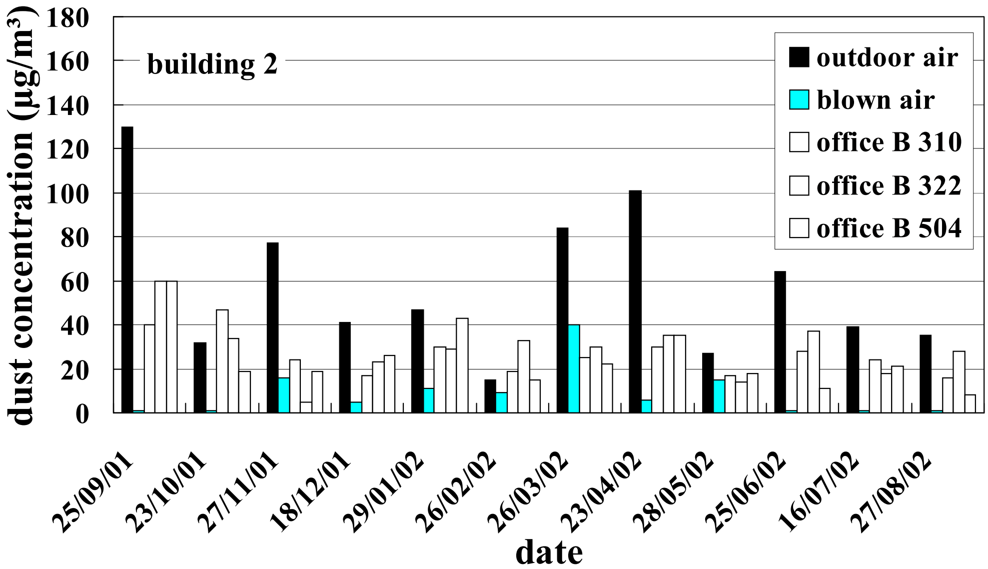

Figure 3b The dust concentration according to time (building 2).

Bacteria concentration values (total) are presented in Figures 4(a) and 4(b) while those concerning fungi (total) are given in Figures 5(a) and 5(b). Concentrations measured in the air blown by the air handling system (building 1 only) are much smaller than those measured in outdoor air. Bacteria concentrations are higher in indoor air than in blown air and can be higher inside than outside. Fungi concentrations are always much smaller inside than outside.

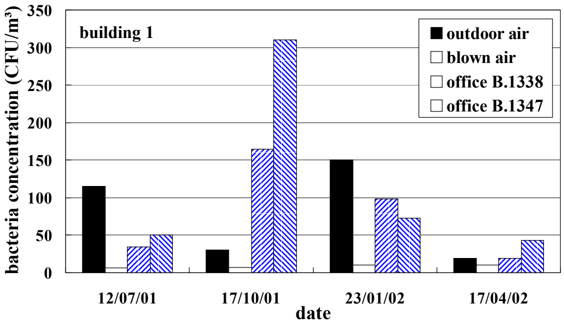

Figure 4a The bacteria concentration (total) according to time (building 1).

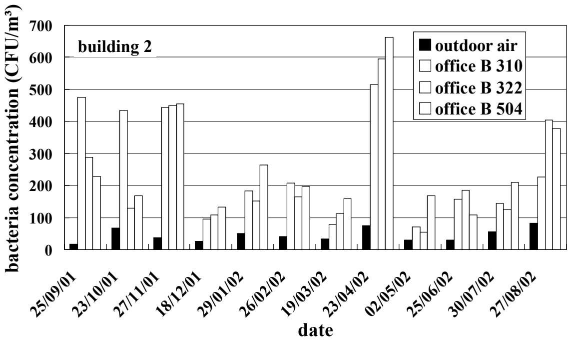

Figure 4b The bacteria concentration (total) according to time (building 2).

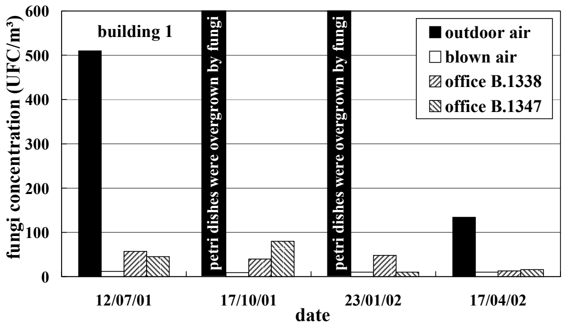

Figure 5a The fungi concentration (total) according to time (building 1).

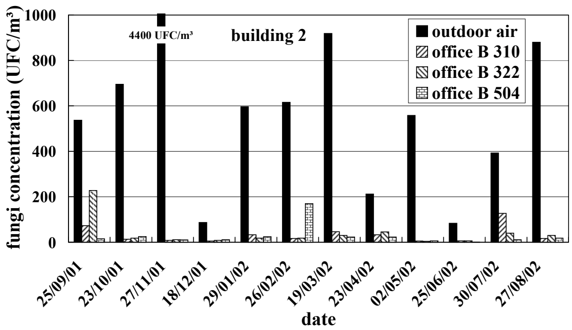

Figure 5b The fungi concentration (total) according to time (building 2).

DISCUSSION

The airflow rate blown by the air handling systems has remained more or less constant during the whole period of the study, which means that the filters did work at 3000 and 2500 m³/h, respectively, for building 1 and building 2. These values are a little bit lower than the common one for this kind of filter (do consider 3400 m³/h) but ensure a proper work of the filters.

In building 1, the filtration efficiency of the air handling system is mainly influenced by the one of the compact filters while the efficiency of the bag filters has almost not changed. The same trend has been observed for the air handling system of building 2 where the filtration efficiency of the air handling system has remained more or less constant, this installation having bag filters as main filters. For both air handling systems, it has been observed that the efficiency of the glass fibre media bag filters has remained more or less constant or has increased very slowly. The phenomenon is quite common for this kind of filter and has been shown in the past (Drangsholt, 1995). The two air handling systems have fine filters that are efficient against the atmospheric aerosol. Dust concentration data as well as air bacteria and air fungi concentrations have confirmed that the filtration efficiency of the air handling systems is high and that the amount of particles entering the building is significantly reduced compared to what is observed outdoors.

Total bacteria level is an indicator of the human occupancy. Bacteria concentrations may be higher indoors than outdoors for building 1 (Figure 4a) and are always higher indoors for building 2 (Figure 4b). Thus, these values are common of indoor spaces where the average is around 350 CFU/m^3 (AFNOR, 1998).

With regards to fungi, indoor concentrations are for both buildings much smaller indoors than outdoors (Figures 5a and b). While an average level may be considered around 20 CFU/m^3 (AFNOR, 1998), data collected during our study show that fungi concentrations are low and that the buildings may be considered as clean.

Also, it has to be taken into account that data presented in the first part of the paper (Ribot *et al.*, 2003) have shown that in both buildings the airflow rate within the offices largely exceed values that are required in France (25m^3/h/person). The two buildings are over ventilated and this can also explain that indoor pollutant levels are low.

CONCLUSION AND IMPLICATIONS

The study has allowed to characterize indoor air quality in building offices over a long period along with its HVAC installation study. Data that we have obtained give more understanding on how indoor air quality may change over a long period. The HVAC installation of these office buildings may be considered as installations working well giving chance to the occupants to live in spaces where indoor air quality may be considered as good. Data presented in this paper show that the air entering the buildings is well filtered and ensure that indoor total dust, bacteria and fungi concentrations are low. Good air filtration can have positive effects on indoor air quality. Also, results presented in the first part of the paper (Ribot *et al.*, 2003) show that good comfort conditions are ensured within the two office buildings. A third office building should be studied in 2003.

ACKNOWLEDGEMENTS

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