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Indoor Air Quality Related to Occupancy at an Air-conditioned Public Building

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ABSTRACT

To characterize the influence of occupancy on the indoor air quality, a public office building with air-conditioning system was selected for this study. The indoor parameters included total bacteria count, total fungal count, temperature, relative humidity, and carbon dioxide concentration. The number of occupants, which varied throughout the day, was recorded in each sample. The samples were taken before the beginning of the working day and during 3 h, at an interval of 30 min between each sampling, and continued for five working days during a week. Correlation analysis demonstrated that occupancy rates were positively correlated with airborne bacteria, CO_2, and temperature. No significant association between the number of occupants and fungus was observed. The results of this study provided information on the variability of indoor air parameters during the time-varying occupancy over the course of the day in at air-conditioned buildings where occupancy was quite dynamic.

Key words: Indoor air quality, air-conditioned, occupancy, office building

INTRODUCTION

The last decade has been characterized by a significant increase of worldwide scientific database in indoor environments. People recognize that indoor air quality may be more important than outdoor air quality because they spend over 70% of their time indoors (Guo et al., 2004). Applications of heating, ventilation and air-conditioning system is known to modify the indoor air quality by means of filtration, humidification, dilution and cooling the outdoor air entering the occupied space. For instances, adequate filtration of outdoor air intake of air-conditioning system through a well-maintained filter can be effective in preventing outdoor microbial contamination associated with outdoor sources of environmental microbes in air-conditioning buildings (Wu et al.,

2005). Air-conditioning system has also been shown to contribute to the rising fungal contamination in indoor air from various components in the system (Ahearn et al., 1997).

The indoor CO_2 level is one commonly used approach which has been referred as an indoor air quality indicator (Lin & Deng, 2003). The acceptability of using measured space CO_2 concentrations to correlate acceptable indoor air quality has been controversial (ASHRAE Standard 62, 2001). It is known that ventilation is necessary to remove the indoor-generated pollutants from indoor air or dilute their concentration to acceptable levels (Seppanen & Fisk, 2004). Successful operation of ventilation systems has long been considered a critical variable affecting the indoor microbial contamination. However, a great number of occupants themselves influence

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the air quality. Despite of the intense interest on indoor air quality some of the parameters that contribute to the pollution of indoor environments are not well understood.

The overall objective of the study was to examine the influence of occupant density on the indoor air parameters in a large office building with mechanical ventilation system.

MATERIALS AND METHODS

Survey protocol
A public office building equipped with central station air-handling equipment without humidity system was selected. The samples were conducted before the beginning of the working day and during 3 h, at an interval of 30 min between each sampling. The number of occupants, which varied throughout the day, was recorded in each sample. The measurements were conducted everyday and continued for five working days during a week.

Microbiological analyses
Indoor air samples (200 L) were collected in the center of the room approximately 1.5 m above floor level using a single-stage sampler (MAS-100, MERCK). Trypticase Soy Agar (TSA) (Acumedia) with 0.5 g/L cycloheximide (Sigma) and Sabouraud Dextrose Agar w/Chloramphenicol (Acumedia) were used for total bacteria and fungi, respectively. Cultures on TSA were incubated at

35 ± 2ºC for 48 h, while agar sabourand plates were incubated at room temperature for 5 d prior to counting. After applying the positive hole correction procedure recommended by MERCK, the results were expressed in colony forming unit per cubic meter (CFU/m^3).

Other parameters
Temperature and relative humidity were recorded simultaneously with a portable digital anemometer (NK 3000, Kestrel, England) and CO_2 was measured using the monitor TESTO 535 (BSRIA Instrument Solution, England).

Data analyses
All independent, continuous variables were tested for linear correlation to each other (Person r).

RESULTS

Since the main interest of this study was to investigate how the indoor parameters would vary as function of occupancy, the graphics presented in Figure 1 (A-F) allowed a detailed analysis of the results distribution. Correlation analysis was conduct between the occupancy and indoor environment parameters inside the air-conditioned building. The results of the coefficients are shown in Table 1. Table 2 summarizes the concentrations of the indoor parameters environmental variables.

Table 1 - Correlation between indoor concentrations of total bacteria (CFU/m^3), total fungi (CFU/m^3), CO_2 (ppm), relative humidity (%), temperature (ºC), particle mass ($\mu g/m^3$), and occupancy (person) inside the air-conditioned building

	Total bacteria	Total fungi	CO_2	Relative humidity	Temperature	Particle mass	Occupancy
Total bacteria	1.00						
Total Fungi	0.06	1.00					
CO_2	0.12	-0.35	1.00				
Relative humidity	-0.24	-0.07	0.06	1.00			
Temperature	0.43*	0.14	-0.12	-0.49*	1.00		
Particle mass	0.53*	0.55*	0.37	0.56*	-0.55*	1.00	
Occupancy	0.58*	-0.08	0.58*	-0.38	0.49*	0.32	1.00

* significant at the level 1%

Table 2 - Distribution of environmental variables

Environmental variables	Mean ± SD	Median	Minimum	Maximum
Total bacteria (CFU/m^3)	541 ± 395	415	110	1955
Total fungi (CFU/m^3)	2863 ± 497	2870	989	5256
CO_2 (ppm)	612 ± 136	609	386	1050
Relative humidity (%)	44 ± 4	44	37	50
Temperature (ºC)	26.3 ± 1.2	26.3	22.5	28.1
Particle mass (µg/m^3)	117,3 ± 90,7	100	0	270
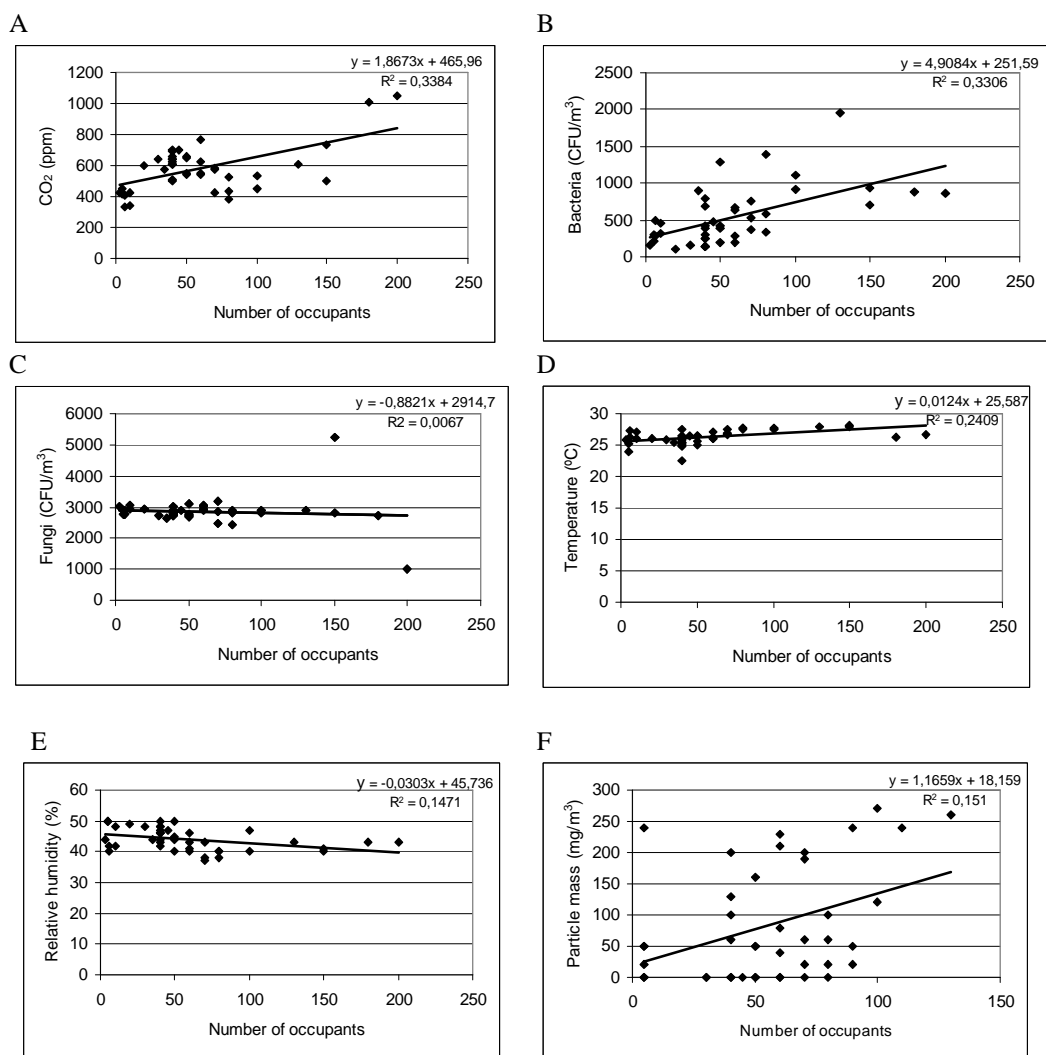
Figure 1 - Occupation and indoor environment parameters inside the air-conditioned building: (A) CO_2 (ppm); (B) Bacteria (CFU/m^3); (C) Fungi (CFU/m^3); (D) Temperature (ºC); (E) Relative humidity (%); Particle mass (mg/m^3) (F).

DISCUSSION

Characterization of environmental air contaminants in a space when it is unoccupied impedes a critical evaluation of indoors air quality for the time-varying occupancy over the course of the day in at air-conditioned buildings where occupancy is quite dynamic. Occupants themselves contribute bioeffluent emissions to the air, which include volatile organic compounds, water vapor, particulate matter, CO_2 and bioaerosols (Engvall et al., 2005). A consistent relationship between the occupancy and corresponding carbon dioxide concentrations was seen in the present study. In two instances, CO_2 level exceeded 1000 ppm.

This implied that the operation of air-conditioning did not significantly reduce the levels of these air pollutant in the building. Health authorities do not generally consider CO_2 at typical indoor concentrations as a health hazard. The 1000 ppm indoor concentration or the 700 ppm difference between the indoor and outdoor CO_2 concentration limit specified in the ASHRAE Standard 62 (2001) is based on its association with human body odor, not with any health or comfort effects of CO_2 itself. Although, the concentrations below 1000 ppm do not always guarantee that ventilation rate is adequate for removal of air pollutants from other indoor sources (Apte et al., 2000). Adequate CO_2 control in a room is possible by limiting the number of occupants or increasing the sources of fresh air in the room.

Epithelial and mucosal surfaces are colonized with bacteria, microflora that become liberated through the normal shedding of skin cells or though aerosolization from mucosal surfaces by talking, coughing or sneezing. High concentration of bacteria contributed by room occupants influenced the air quality independent of an infectious disease (Bartlett et al., 2004). The geometric mean indoor concentration of airborne bacterial was 541 CFU/m^3 ranging from 110 to 1955 CFU/m^3.

Presently, there is no sufficient information on dose-exposition relationships regarding viable and cultivable biological agents (Dacarro et al., 2003). Despite the intense interest in the role of bioaerosols to health, there is no consensus for regulatory limits on airborne bacterial concentrations in indoor air (Bartlett et al., 2004). A significant correlation between occupant density and indoor bacteria concentration support the

future application of using bacteria levels as an indicator for indoor-originated contamination.

For fungus, although an elevated indoor concentration was observed it was not found related to a greater number of occupants. These data were in agreement with the fact that the most probably source of air contamination by these microorganisms were indoor sources (Roos et al., 2004). Actually, the reference value for fungus is limited to 750 CFU/m^3, suggesting that higher values must have a fungi source that should be investigated (Rao et al., 1996). The currant data was able to demonstrate that the fungal concentrations could be associated with indoor source of contamination other than human origin.

The effect of air temperature on thermal comfort is well known, but its effect on air quality is not widely recognized (Seppänen & Fisk, 2004). This study also demonstrated that occupancy in air-conditioned indoor environment had impact in the temperature. This information could be used as a parameter of excess of occupants/m^3.

The pollution of indoor environments has achieved great importance first and foremost by the increasing number of officially reported cases involving people with health problems related to their professional environment, reduce productivity and increase absence (Wyon, 2004). Public buildings are representative of a variety of building styles, ages, and construction materials. Many office building were built before forced air ventilation became a routine feature, and there is a need to provide a baseline for what is considered to be acceptable for these environments.

Adequate air change is necessary in air-conditioned buildings for diluting many air pollutants of indoor origin. It is known that ventilation is necessary to remove the indoor-generated pollutants to acceptable values. But as the limit values of all indoor pollutants are not known, the exact determination of required ventilation rates based on pollutants concentrations and associated risk is seldom possible (Seppänen & Fisk, 2004). The effects of ventilation on indoors air quality and health is a complex issue. Most of the existing literature indicates that increasing ventilation rate will be an effective way to improve indoor air quality; however, in most cases, it results in the consumption of more energy (Lin & Deng, 2003). A limitation of the present study was that the ventilation rate could not be collected.

In conclusion, although more studies would be needed to determine the extent of occupancy in indoors parameters, its clear that many offices would not be able to comport a high number of occupants maintaining a good air quality. Evidences showed that ventilation was necessary to assure the adequate dilution of contaminants generated in the occupied space. Ventilation systems for spaces with variable occupancy may provide sufficient dilution to maintain contaminant concentrations within acceptable levels at all time.

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RESUMO

Com o objetivo de caracterizar a influência da ocupação na qualidade do ar interior, um edifício público com sistema de ar condicionado foi selecionado. As variáveis ambientais consideradas incluíram contagem total de bactérias e fungos, temperatura, umidade relativa e concentração de dióxido de carbono. O número de ocupantes, que variou durante todo o dia, foi estimado em cada amostragem. As amostras foram coletadas antes do início do expediente de trabalho e durante 3 horas, em intervalos de 30 minutos, por 5 dias úteis consecutivos. A análise de correlação demonstrou que a taxa de ocupação foi correlacionada positivamente com a concentração de bactérias, dióxido de carbono e temperatura. Nenhuma associação significativa foi observada entre o número de ocupantes e concentração de fungos. Os resultados deste estudo fornecem informações quanto à variabilidade nos parâmetros do ar interior no decorrer do dia em um edifício onde a ocupação é dinâmica.

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