COMPARISON OF IAQ BETWEEN AN AIR-CONDITIONED BUILDING AND A NATURALLY VENTILATED BUILDING DURING HEATING SEASON

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ABSTRACT

Field measurements were made during the heating season to compare IAQ between an air–conditioned building (Building A) and a naturally ventilated building (Building B) situated in the centre of Pyongyang and similar in architectural design, number of occupants and years of occupation. Compared with Building A, Building B had a significantly lower mean air temperature (with greater influence of outdoor temperature), non-significantly higher relative humidity, higher air velocity, significantly lower air exchange rate, non-significantly higher airborne particle concentration, similar airborne bacteria concentrations but higher indoor fungal concentrations. There were no great differences in bacteria and fungal species indoors between two buildings. The mean levels of all parameters were within acceptable ranges in both buildings. In conclusion, IAQ in the air-conditioned building is better than in the naturally ventilated one in the heating season in our study and the main reason is the difference of air exchange rates. Further study of IAQ is expected in both buildings during cooling season.

INTRODUCTION

Urban outdoor air has been gradually polluted because of population concentration in cities and expanded heavy traffic. The DPR of Korea is not without this problem and has made efforts to prevent outdoor air pollution and create the better outdoor environment. Recently, many modern and high buildings, as well as great monuments have been built in our country and people spend about 90% of their lives in indoor environment.

Only recently has there been a research interest in indoor air quality and its health effect, or in establishing scientific regulations for the indoor environment. There have been many research papers about investigation of IAQ in modern buildings in equipped with various kind of HVAC system in developed world (1,2,3). However, few investigations have been made in relation to indoor air quality and its health effect in the DPR of Korea.

It has been known that IAQ can be affected by various kind of population sources such as outdoor air, occupants‘ activities, building materials, the kind of HVAC system and others (4). In recent times, there have been concern that people living in air-conditioned buildings show much more complaints about poor IAQ than those who live in naturally ventilated buildings in our country, as in other countries. However, there has not been scientific research to investigate the basis of this concern. This paper begins to supply the research evidence.

SUBJECT AND METHODS

Subject buildings

Two hotel buildings situated in the centre of Pyongyang were selected. The selected buildings were similar in architectural design, years of completion dates of construction and density of occupation. However the ventilation styles are different, one is air-conditioned (Building A) and the other one is naturally ventilated (Building B). Table 1 shows brief information on the two buildings. In each building the measurements were conducted in the dining hall, on the second floor.

Table 1. Summary of measured buildings

	Building A	Building B
Years of occupation	14	16
Gross floor area (m^2)	71, 704	51, 652
Ventilation system	Central air-conditioning system	Natural ventilation & local cooling and heating coil
No. of floors	40	20
Volume (m^3)	1560	1530

Measurement items

The measurement items in indoor and outdoor environments included the air temperature, relative humidity, air velocity, suspended particulate matter, rate of ventilation, airborne bacteria and fungi. The measurements were made on Thursday every week during the heating season from November 1997 to March 1998.

To decide the measurement points, a room was evenly divided into nine imaginary sectors. Then, parameters of IAQ were measured at 110 cm above floor level of each sector. Simultaneously outdoor air quality items were measured on the balcony of the second floor. Table 2 indicates the measurement items and methods.

The ventilation rates were measured by air velocity and area size of air exhaust duct (5). The microbial air samples were collected onto the normal agar plate for bacteria and Sabouraud agar medium with added Chloramphenichol for fungi. The samples were incubated for 48 hours at 37°C for bacteria and for 96 hours at 25°C for fungi before counting formed colonies and identification of species.

Table 2. Measurement items and instruments

Measurement items	Instruments
Temperature	Digital thermo-Hygrometer (Type TRH-CX, SIBATA)
Relative humidity	
Air velocity	Silicon Anemometer (ISA-31, SIBATA)
Airborne particles	Laser dust monitor (LD-1H, SIBATA)
Airborne bacteria	Portable air sampler (SAS SUPER 90, pbi)
Airborne fungi	

RESULTS AND DISCUSSION

Temperature

During the measurement period, the mean indoor air temperature in building A was 21.8 (18-24) °C and was well within the comfort temperature range. The mean air temperature in building B was 14.6 (11-19) °C and significantly lower than in building A. Figure 1 shows the variations of air temperature in the two buildings. In building A, there was no any relation between temperature indoors and outdoors, but indoor air temperature in building B was a little influenced by outdoor temperature. This means there was insufficient heating in building B.

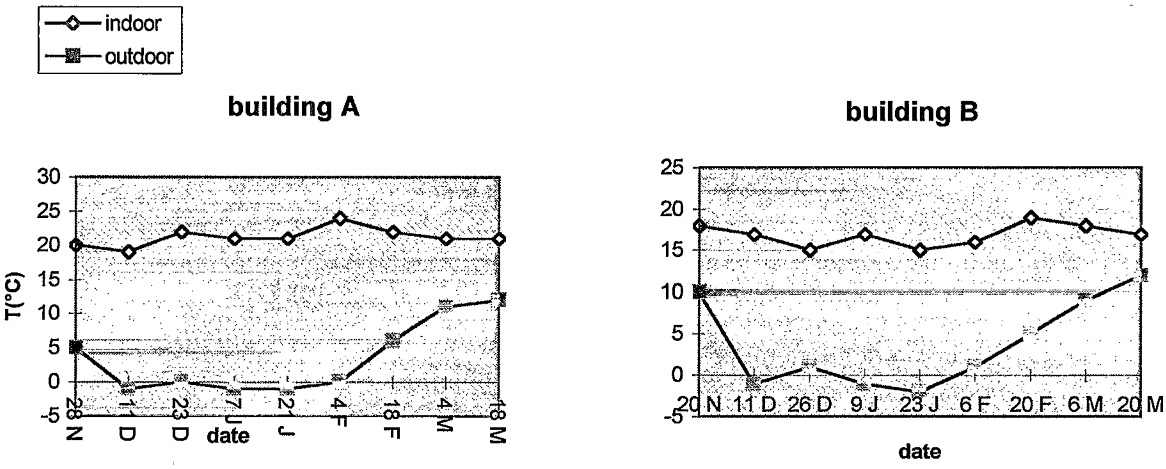

Figure 1. Air temperature variations in two buildings during heating season

Relative humidity

The mean relative humidity of the indoor air in building A was measured as 37.3 (32-44) % and in building B as 41.4 (35-52) % with no significant difference between two buildings ($p=0.1$). During heating season, the relative humidity of indoor air in two buildings remained well within an acceptable range (24-45 %).

Air velocity

The indoor air velocity in building A was measured from 0.1 to 0.25 m/s (mean 0.19 m/s) and rather satisfactory. But in building B, mean indoor air velocity was 0.032 (0.010-0.043) m/s which was much lower than in building A ($p<0.001$) and also much lower than indoor guidelines (0.10 ± 0.15 m/s). This situation in building B could indicate an unfavourable ventilation rate. In the same period, there were no significant differences in outdoor wind velocities between the two buildings.

Airborne particulates

The concentration of airborne particulates in building B was rather higher than in building A, but with no significant difference ($p=0.2$). The mean level of indoor particulates in building B

(131.7 μg/m^3) was within hygienic guideline (150 μg/m^3), but about 40% of individual measurements exceeded that guideline. There was no difference in outdoor particulate levels between two buildings (p=0.8).

Airborne microbes

In building A, the level of indoor airborne bacteria was 62 (25-132) cfu/m^3 which was a little lower than in building B, but with no significant difference. The average indoor concentration of fungi was 68 (28-127) in building A and 119 (87-197) cfu/m^3 in building B, a significant difference ($p<0.05$). The indoor airborne bacterial and fungal concentrations of the two buildings were lower than winter guidelines (bacteria; 450 cfu/m^3, fungi; 500 cfu/m^3). These results appear to reflect the low level of activity of occupants during the measurements.

The level of outdoor bacteria and fungi in two buildings were much higher than indoors, but there were no significant differences between two buildings.

Cocci among isolated bacteria were 81.6 % in building A and 83.3% in building B, and bacilli 18.4 % and 16.7%, respectively. In indoor air of both buildings, the cocci were much higher than bacilli. *Aspergillus, Penicillium* and *Cladosporium* were the main fungal species (above 90%) isolated indoors and these percentages were similar in both buildings. The special feature of fungi in outdoor air was that *Aspergillus* species dominated (47–70 %).

Ventilation rate

Outdoor exchange rate (m^3/h) and ventilation rate (air changes/h) in building B were significantly lower than in building A. The ventilation rates were 1.95 air changes/h in building A and 0.66 air changes /h in building B as mean values ($p< 0.001$).

CONCLUSION

Table 3 summarises the values of indoor air parameters in the two buildings. We recognise that our methodology for measuring ventilation rate was not ideal, but the difference between the buildings was quite large. Because of the low ventilation rates in building B, the concentrations of airborne particles, bacteria and fungi seem to be rather higher than in building A. But all measurement values were not very different from the hygienic guidelines of our country as well as of other countries.

Table 3. Comparison of measurement values (mean ± SD) of indoor air in both buildings

	Building A	Building B	P
Outdoor exchange rate (m^3/h)	3006.5 ± 601.2	1036.8 ± 423.4	<0.001
Ventilation rate (air changes/h)	1.95 ± 0.39	0.66 ± 0.29	<0.001
Air velocity (m/s)	0.19 ± 0.05	0.03 ± 0.02	<0.001
Airborne particulate (μg/m^3)	54.6 ± 26.1	131.7 ± 79.1	0.2
Airborne bacteria (cfu/m^3)	62.4 ± 40.8	74.1 ± 52.5	0.6
Airborne fungi (cfu/m^3)	68.4 ± 39.8	119.1 ± 51.4	<0.05

In conclusion, during the heating season the indoor air quality as judged by the measured parameters was rather better in the air-conditioned building than in naturally ventilated building. Although there are some recent data that air-conditioned buildings cause more complaints about poor indoor air quality, we cannot say just now about it simply based on the data during heating season. Considering our advanced data about high microbial contamination indoors during summer, it could be interesting to make a survey in both buildings also during the cooling season.

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