Measured IAQ in two new blocks of flats

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ABSTRACT
Two similar blocks of flats have been built for people with respiratory diseases. The buildings have a clean and effective ventilation system and low emitting building materials. The ventilation system is a centralized supply and exhaust air system, either based on demand (Building A) or user controlled (Building B). Total volatile organic compound (TVOC) levels and concentrations of ammonia and formaldehyde were measured in one apartment on each of the six floors of both buildings before occupants moved in and after 3 and 7 months and after one year of occupancy. The indoor air quality (IAQ) achieved the high quality target level after 7 months of occupancy and remained at this level during the 1-year follow-up period.

INDEX TERMS
TVOC; Formaldehyde; Ammonia; New building; Indoor air quality

INTRODUCTION

The quality of indoor air is important for the well being of human beings. For people with respiratory diseases and allergies, it is essential. The Pulmonary Association achieved the indoor air quality class S1 (FiSIAQ) in the block of flats Puijonkartano built in Kuopio in 1995–1996. The indoor air of the apartments have three to five times less impurities irritating respiratory tracts than authorities require or that is accepted in an ordinary building of good air quality (Tuomainen *et al.*, 1997, 2001, 2003). The 'Tuusulan Silmu' block of flats had the same target. The flats were designed and built for rental to occupants with respiratory diseases and factors affecting indoor air quality (IAQ) were carefully considered.

The study was designed to include two blocks of identical flats except for the method of controlling ventilation. In one of the blocks (Building B), ventilation has to be adjusted by the occupants. In the other (Building A), air quality is adjusted automatically. The factors affecting IAQ were carefully considered during the design period. Recommendations made in the Classification of Indoor Climate (FiSIAQ, 2001) were taken into account. Project designers and builders were given training in prevention of problems with indoor air. The main design features to achieve healthy building were:

- use of tested and low emission building materials (to avoid odour emissions of materials);
- moisture control during construction process (to minimize the material emissions);
- clean construction site (to protect the flats and also the workers to be exposed to dust);
- clean and effective ventilation system (to control IAQ during the occupancy time);
- central vacuum cleaner (to make the flats easy to clean).

The construction work was started in January 2000. The buildings were completed in February 2001 and fully occupied in April 2001. The process of control used has been described in more detail by Pirinen (2000).

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MATERIALS AND METHODS

Studied Buildings

There are in all 43 flats in the two buildings, with an overall floor area of 2585 m^2 (the mean area per flat is 60 m^2). Most of the flats (33) have two rooms and a kitchen. The other 10 flats have three rooms and a kitchen. All of the flats have a sauna linked to the bathroom. Both buildings have a central mechanical supply/exhaust ventilation system. The rated supply air current value per unit area varies from 0.7 to 1.1 $l/s/m^2$. The most typical value is approximately 0.9 $l/s/m^2$, equivalent to approximately 1.2-fold air changes per hour. All flats and bathrooms have floor heating. Both buildings are similar, the only difference being the control solution of the ventilation system. The prefilter of supply air is EU5 and the fine filter is EU8. Supply and exhaust fans have speed control system with constant pressure control. The pressure losses in the vertical ventilation ducts are very low in order to maintain constant pressure level in the vertical duct system. There are separate dampers in each flat for supply and exhaust air. For the kitchen hood, there is separate time controlled damper in the hood (maximum 30 min).

The most significant difference between the two buildings is the method of controlling ventilation. In building A, the ventilation system is demand controlled. Relative humidity in bathrooms and CO_2 concentrations in bedrooms are measured and ventilation rates are controlled in order to keep RH and CO_2 below target values 50% and 600 or 1000 ppm. In building B, occupants can control the ventilation rate of single flats.

IAQ Measurements

Levels of ammonia, formaldehyde and TVOC in indoor air were measured in six flats per building. Measurements were made before residents moved in, and after three (only in three selected flats per building), seven months and one year of occupancy. Methods and equipment used are summarized in Table 1.

Table 1 Summary of methods and equipment used to evaluate IAQ

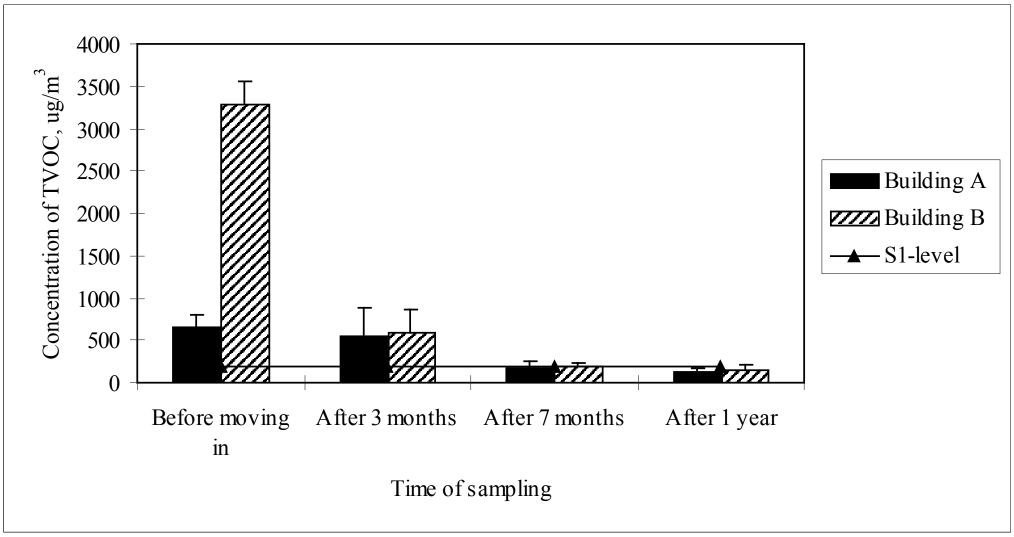
Parameter	Unit	Method/equipment	Sampling time
Temperature	^oC	Electrical measuring instrument (TSI Q-trak 8551)	1 h
Relative humidity	%		
Carbon dioxide	ppm		
Ammonia (NH_3)	$\mu g/m^3$	Collected in dilute sulphuric acid and determined using an ion-specific electrode	1.5–2 h
Formaldehyde (H_2CO)	$\mu g/m^3$	Collected in cartridges coated with dinitrophenylhydrazine (DNPH) and determined using a high-pressure liquid chromatograph (HPLC) equipped with a diode-array detector (DAD).	1.5–2 h
Total volatile organic compounds	$\mu g/m^3$	Collected in Tenax TA and determined using thermal desorption, gas chromatographic separation and detection of individual volatile organic compounds by means of a mass selective detector	1.5–3 h

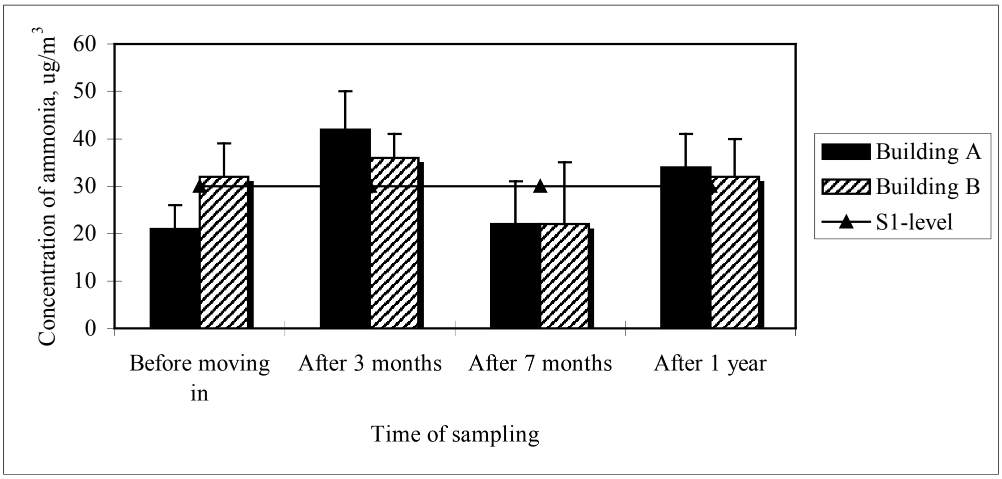
RESULTS AND DISCUSSION

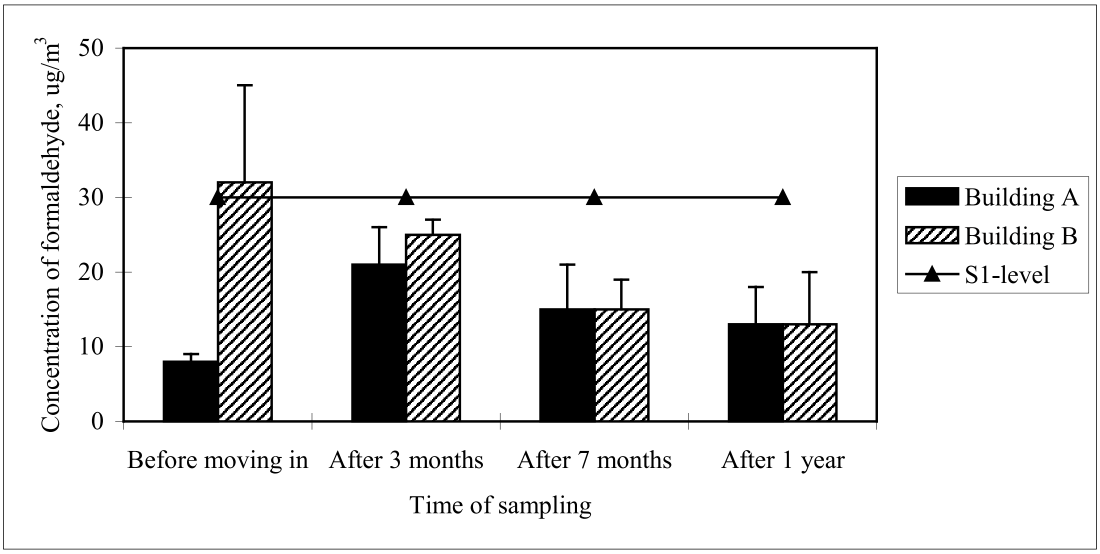
The concentrations of TVOC, ammonia, and formaldehyde are shown in Figure 1. The ventilation rates were approximately 1.2-fold air changes per hour during the measurements time.

The data indicate that TVOC levels in the new building immediately after its completion exceeded the most demanding target S1 level (FiSIAQ, 2001). However, levels decreased rapidly during the first months of occupancy. TVOC values reached target level (<200 µg/m^3) seven months after building had been completed.

Figure 1 Concentration of TVOC, ammonia and formaldehyde and over 1-year follow-up period.







Ammonia values were at target level (<30 μg/m^3) on completion of the buildings but increased slightly after occupants moved in. These results proved that also the occupants and their habits have effects on the ammonia levels. Formaldehyde values were at S1 level (<30 μg/m^3) throughout the monitoring period except when they were first measured in Building B immediately after its completion. In general, average levels of TVOC, ammonia, and formaldehyde were lower in Building A than in Building B at each time of measurement, probably because humidity was better controlled in Building A than in Building B during construction. During the construction of building A, temporary roof was laid in order to ensure that rain and water does not get into the structures.

The results are consistent with earlier observations by us relating to a similar building in Kuopio (Tuomainen *et al.*, 2001, 2003). They also provide additional evidence of the benefits of working in accordance with Classification of Indoor Climate (FiSIAQ, 2001) during construction projects. During 2003, the opinions of the occupants will be available. The effect of the possibility of ventilation adjustment on IAQ and energy consumption has also been studied in detail. The automatic control system seems to be the more economical solution for the control of IAQ. The only negative factor is the lack of individual control when it is needed.

CONCLUSIONS

This case study supports the findings that it is possible to attain good IAQ by careful design, proper materials and equipment and in high-quality construction with reasonable additional costs. The high-IAQ was achieved during the first months of occupancy. In addition, the high-IAQ achieved can also be maintained during the one year of occupancy.

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