# Effect of cleaning on symptoms and percieved IAQ in an office building

H. Kokotti[a], R. Halonen[a,*], L. Kujanpää[b], J. Tarhanen[a], E. Korhonen[c], P. Lavonen[d], M. Linnainmaa[b], J. Honkanen[d], M. Reiman[b]

[a]*University of Kuopio, Finland;* [b]*Regional Institute of Occupational Health, Kuopio, Finland;* [c]*University of Jyväskylä, Finland;* [d]*Medivire, Kuopio, Finland*

## ABSTRACT
Many workers in an office building complained about IAQ. No moisture damage was found in the offices, which were, however, painted and carpeting was changed. Ventilation ducts were cleaned and the supply and exhaust air vents were installed in every room. Shortly after the repair the workers developed symptoms. A thorough survey of IAQ including microbes and particles and volatile organic compounds was conducted twice after the repair. Between surveys the rooms were cleaned for 2 months twice a week with more effective practices than before. The first microbial and particle measurements before the intervention cleaning suggested that the ventilation system was partly responsible for complaints. Occurrence of some indicator microbes suggested moisture damage in the office. The microbial and dust concentrations clearly decreased after the effective cleaning period. The total concentrations of VOCs were low ranging from 19 to 220 $\mu g/m^3$ already before the intervention cleaning.

## INDEX TERMS
Symptoms; Cleaning; IAQ; Office building; Remedial action

## INTRODUCTION
Poor indoor air quality (IAQ) often causes symptoms and complaints among users of a building. Factors deteriorating indoor air include, e.g. dust, water damages and contaminated ventilation system (Gyntelberg *et al*., 1994; Seuri *et al*., 2000; Mendell *et al*., 2002). If there are no obvious signs of water damages, remedial actions to improve IAQ are usually focused on ventilation or the quality of cleaning. In non-problem buildings, duct cleaning has been shown to improve percieved IAQ and the prevalence of work-realed symptoms, although no measurable effect could be seen in supply air quality (Kolari *et al*., 2002). The purpose of cleaning is to remove particulate and chemical impurities from surfaces. Effective cleaning has been shown to lower the concentrations of volatile organic compounds (VOC) and dust in indoor air (Franke *et al*., 1997). The aim of this study was to find out whether effective cleaning has any effect on symptoms and perceived air quality.

## MATERIAL AND METHODS
Most of the 26 workers in the office reported symptoms connected to IAQ (e.g. coughing, eye and skin irritation, throat ache, breathing disability). No moisture damage was found in the offices, which were, however, painted and carpeting was changed. Ventilation ducts were cleaned and air tightened, and the supply and exhaust air vents were installed in every room. The symptoms disappeared during the stay in temporary workrooms.

After the repair the same workers moved back to their own rooms. Shortly after the move they contacted the occupational health care because of their symptoms, and the second questionnaire was conducted. During the next spring we started a thorough survey of IAQ of

*Corresponding author.

every room including microbes and dust on surfaces and in the ventilation system and VOCs in room air. For 2 months after the summer holidays the rooms were cleaned twice a week instead of the earlier once a week interval with more effective practices than before. In the beginning of this intervention cleaning dust was removed from surfaces of shelves, lamps and ventilation ducts. The surfaces were swept with a wet cloth treated with disinfectant. The IAQ survey was repeated twice: at the end of the cleaning period and a month after the cleaning period.

**Microbes**
The microbial contamination of surfaces and air was examined in all workrooms and in ventilation system. Surface samples were swept from surfaces and cultivated directly on cultivation plates. Air samples were collected by a six stage cascade impactor (Andersen Inc.) onto three different cultivation media (Rose Bengal malt agar (RBM), dichloran glycerol agar (DG18) and tryptone yeast glucose agar (TYG)) at the same time. In addition, the material samples of supply air filters were taken and cultivated by the dilution method.

**Dust and Fibres**
Relative dust concentrations (BM Dust detector) on the floor, the window board and above shelves in each office room after repair work and before cleaning, during cleaning and just at the end of the cleaning period for 2 months were measured. Fibres on the surfaces near the supply air vents were collected in each office room with the tape utilized in dust sampling. The fibres were analysed using a microscope.

**Volatile Organic Compounds**
Volatile organic compounds were collected into Tenax GR adsorbent during 2 h and they were analysed by a gas chromatograph having a mass selective detector (HP 5680/5973 MSD)

**Supply and Exhaust Airflow Rates**
Airflow rates were measured from the vents by a balometer, a thermal anemometer and a manometer.

**Symptoms**
The symptoms of 26 persons were surveyed by questionnaires modified from the one reported by Andersson *et al*. (1993). The workers filled daily the questionnaire for 7 days before and after the repair work and move in. In addition, the last survey was conducted 1 month after the effective cleaning period.

## RESULTS

**Microbes**
Before the effective cleaning period, average concentration of fungal spores in air samples ($n = 26$) was 40 cfu/m$^3$ (RBM) (range 7–204 cfu/m$^3$) and 120 cfu/m$^3$ (DG18) (range 24–283 cfu/m$^3$). Fungal spore concentrations in outdoor air were 445 and 575 cfu/m$^3$, respectively. Air samples from offices contained mostly *Cladosporium, Penicillium* and *Geotrichum*. There were similarities in microbial composition of air filter material samples and surface samples taken from the offices, the presence of e.g. *Acremonium* and *Paecilomyces*. In many offices we found small amounts of several uncommon microbes, e.g. *Aspergillus (A.) penicillioides, A. versicolor, Chaetomium, Phialophora, Trichoderma* and *Wallemia,* which did not occur in outdoor air samples at the same time.

At the end of the cleaning period, the microbial concentrations of indoor air diminished significantly in 25 (96%) offices. The average concentration of fungal spores was 7 cfu/m$^3$ (RBM) (range <2–132 cfu/m$^3$) and 8 cfu/m$^3$ (DG18) (range <2–162 cfu/m$^3$). Fungal spore concentrations from outdoor air were not measured, because the ground was covered with snow, and the fungal concentrations were thus expected to be less than the detection limit (2 cfu/m$^3$). Samples taken from offices still contained, however, small amounts of untypical microbes like *Aureobasidium, Acremonium, Botrytis, Eurotium, Mucor, Paecilomyces*, Sphaeropsidales, *Trichoderma, Wallemia, Ulocladium*, red yeasts, and actinobacteria (*Streptomyces*).

**Dust and Fibres**

The fibre concentration ranged from 1 to 49 pieces/cm$^2$ on ventilation ducts (Figure 1). The fibres were analysed and found to be similar to mineral fibres.

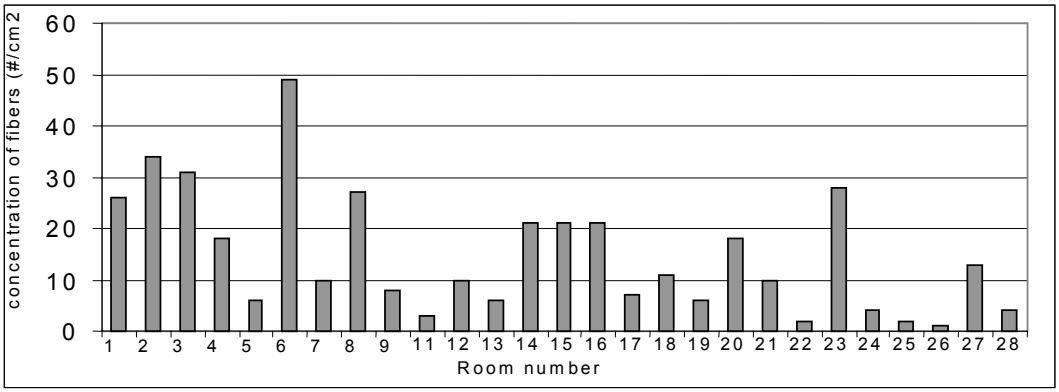


**Figure 1** The concentration of fibres on the surfaces near the vents of the supply air ducts in each office room (#/cm$^2$).

Relative dust concentrations on the floor, on the window board and on surfaces above shelves in each office room were slightly decreased after effective cleaning period of 1 month and clearly decreased after a 2 month period. The reduction in percentages of dust were 41% on the floor, 73% on the window board and 10% on surfaces above shelves (Table 1. and Figure 2).

**Table 1** The average values of relative dust concentration on the floor, on the window board and on surfaces above shelves in 28 rooms during different cleaning periods

| Sampling site | Before cleaning | Cleaned for a month | Cleaned for 2 months |
|---|---|---|---|
| On floor | 2.7 | 2.6 | 1.6 |
| On window board | 2.2 | 1.1 | 1.6 |
| Upper shelves | 3.0 | 2.6 | 2.7 |

**Volatile Organic Compounds**

The total concentrations of volatile organic compounds (TVOC) in each room were negligible ranging from 19 to 220 µg/m$^3$ (arithmetic mean 85 µg/m$^3$) already before the effective cleaning period and decreased slightly after the cleaning (range 15–214 µg/m$^3$, arithmetic mean 73 µg/m$^3$). Individual compounds were common indoor VOCs. Extremely low concentrations of microbial VOCs (≤2 µg/m$^3$) were analysed only in a few rooms.

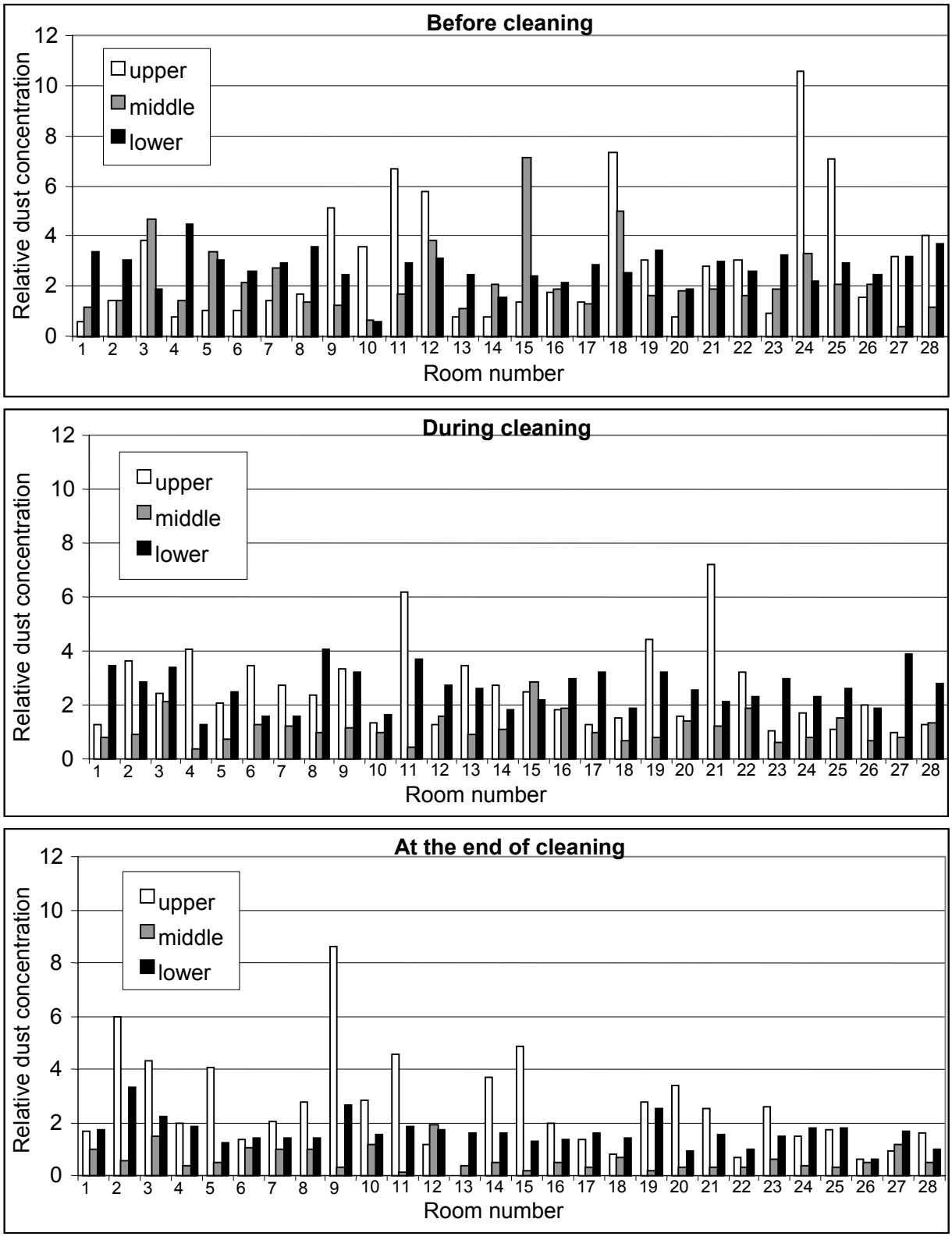


**Figure 2** Relative dust concentrations (BM Dust detector) on the floor (lower), on the window board (middle) and above shelves (upper) in each office room after repair work and before cleaning, during cleaning and just at the end of the cleaning period for 2 months.

**Supply and exhaust airflow rates**

During the first measurement period after the repair work, 8 rooms were pressurized (air flow difference between the supply and exhaust air flows was ≥10 l/s), the airflows of 12 rooms were balanced and 9 rooms were slightly depressurized due to greater exhaust flows than supply flows. No great changes in airflow rates could be detected at the end of the cleaning period (Figure 3).

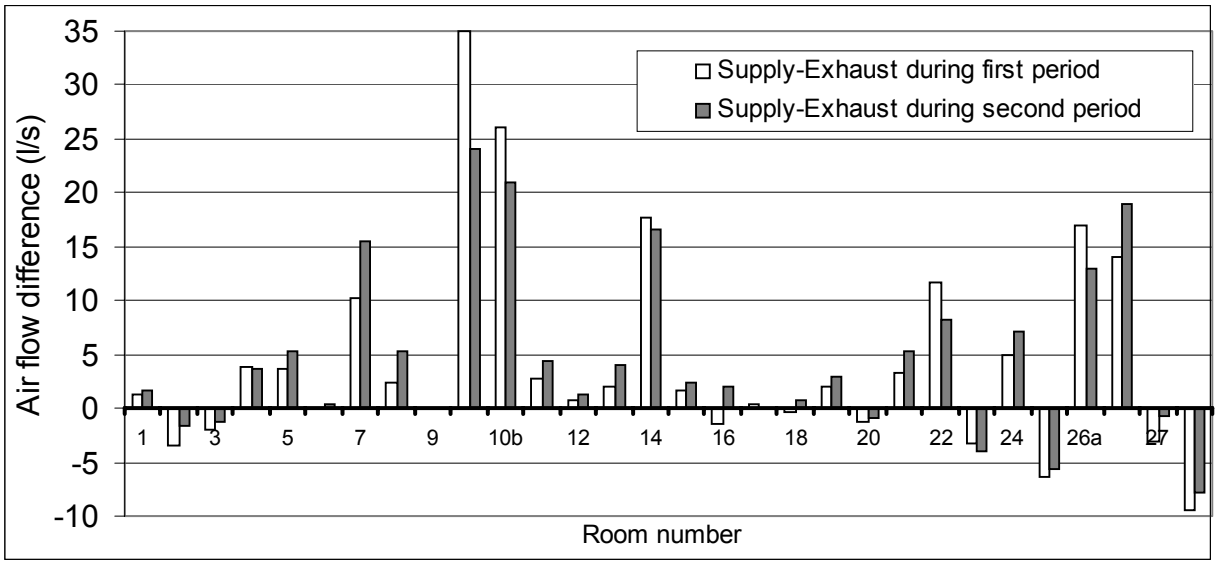


**Figure 3** Differences between the supply and exhaust airflow rates (l/s) in office rooms ($n$ = 28) during the first and the second measurement periods. The data for room 9 was not available.

**Symptoms**

Most of the workers (15/26) in the office reported symptoms connected to IAQ prior to minor repair and cleaning of ventilation ducts. After these remedial actions symptoms became even more prevalent (18/26). The effective cleaning practices carried out for 2 months did not lower the prevalence of symptoms (Table 2).

**Table 2** The reported symptoms of the workers (26 persons in total) before (in 2001) and after the repair work (in 2002) and after the effective cleaning period (in 2003) in the offices ($n$ = number of workers, % = percentage or prevalence of symptoms).

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| | Total office area (groups A and B) | | Rooms on the side of the next building (group A) | | | Rooms on the side of the roof of the first floor (group B) | | |
|---|---|---|---|---|---|---|---|---|
| Year | Workers who answered the questionnaire | | Workers having symptoms | | | Workers having symptoms | | |
| | *n* | % | *n* | % (in group A) | % (in groups A and B) | *n* | % (in group B) | % (in groups A and B) |
| 2001 | 21 | 81 | 10 | 67 | 48 | 5 | 33 | 24 |
| 2002 | 24 | 92 | 13 | 72 | 54 | 5 | 28 | 21 |
| 2003 | 15 | 58 | 10 | 71 | 67 | 4 | 29 | 27 |

## DISCUSSION

Microbial and particle measurements in the offices referred to the ventilation system as a source of some microbes and particles, and thus being partly responsible for complaints. Further, the occurrence of some moisture indicating microbes (e.g. *Aspergillus versicolor, Trichoderma* and actinobacteria) found neither in the ventilation system nor in outdoor air was similar in adjacent rooms suggesting moisture damage in the offices (The international workshop *Health Implications of Fungi in Indoor Environments,* 1992). However, the microbial and dust concentrations were decreased significantly after the effective cleaning period, the effect seen also by Franke *et al*. (1997). No such effect was seen as to VOCs, the concentrations of which were low already before the effective cleaning period. Symptoms have reappeared and even increased after repair work and effective cleaning of offices and ventilation ducts. This indicates that there might be an ongoing problem in this building. In the last questionnaire the answering percentage was lowest (about 60 %). This could be due to the fact that some persons have moved away and three new people have started working in the area and they have no motivation for answering the IAQ questionnaire. This might have minor effects on the results.

## CONCLUSIONS AND IMPLICATIONS

Thorough cleaning lowers the amounts of dust and microbes in offices, but has no effect on symptoms and perceived IAQ if there are other persistent factors responsible for the poor IAQ. Based on the results obtained in this study, thorough technical inspection of constructions and subsequent necessary renovations will be made in these offices.

## ACKNOWLEDGEMENTS

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