

# Coincidence of microbial findings, complaints and symptoms in a building

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## ABSTRACT

Microbial sampling was used to study indoor air quality in a building where the employees had complained about IAQ for many years. In addition, the symptoms and complaints of the employees working in the building were surveyed by MM40-questionnaire. Workers complained about dust, dirt, dry, stuffy air and unpleasant odor. Tiredness and irritation of upper respiratory tracts and eyes were the most common symptoms. IgG antibodies against microbes commonly found in water damaged buildings, were determined from the serum samples of the employees. Over half of the serum samples contained IgG antibodies against microbes found in offices or in supply air systems. The fine filter of every supply air system included, e.g. *Aspergillus fumigatus*, against which antibodies were common. The microbial findings, IgG antibodies against microbes and workers' symptoms indicated microbial exposure originating from ventilation system or moisture damaged constructions.

## INDEX TERMS

Building; IAQ assessment; Symptoms; Microorganisms; Immune response

## INTRODUCTION

Exceptional exposure to microbes in buildings may cause health problems (Verhoeff and Burge, 1997; Peat *et al.*, 1998). Health consequences are mostly respiratory symptoms and diseases, but also unspecific symptoms like tiredness and headache (Peat *et al.*, 1998, Bornehag *et al.*, 2001). Microbial concentrations may fluctuate locally and temporally. Results of occasional microbiological measurements do not necessarily reflect exposure exactly. Questionnaires and microbe-specific IgG antibodies are used to ascertain the associations between microbial findings, exposure and symptoms.

## METHODS

This study was conducted in the areas of four floors and four mechanical ventilation systems (A, B, C and D) in a building where the workers had complained about IAQ for many years. Microbiological sampling, questionnaire and antibody analyses were used to assess factors affecting the indoor air quality in an office building. No thorough technical investigation of the building was conducted, although exceptional moisture was detected in some parts of outer walls.

Air samples were taken with a six-stage Andersen impactor directly on growth media. Surface samples (Martyny *et al.*, 1999) were wiped from 10 × 10 cm<sup>2</sup> area either into sample buffer or directly on growth media (Reiman *et al.*, 1999, 2002). Material samples were taken from fine filters of the supply air units. Mesophilic fungi were cultivated on malt-extract–Rose Bengal agar (Hagem), dichloran–glycerol agar (DG18), and mesophilic bacteria including actinobacteria on tryptone-yeast-extract-glucose agar (TYG). The plates were incubated at +25±3°C for 7 days. Mesophilic fungi from surface samples were also cultivated on 2% malt-extract-agar (M2). Thermotolerant fungi from filter material were analysed from M2-agar after 5 days' incubation at +40±3°C. After incubation the number of colony forming units (cfu) was counted. Fungi were identified using common mycological procedures. The

results are expressed as cfu/m<sup>3</sup> (air samples), cfu/cm<sup>2</sup> (surface samples analysed by dilution plating), cfu/g (material samples) or on relative scale (–, +, ++, +++, +++++ according to the number of cfu/plate) (surface samples analyzed by direct plating). The MM-40 questionnaire is widely used to assess indoor air problems (Mizoue *et al.*, 2001). All the 300 employees working in the study area were asked to participate. Questions deal with perceived IAQ problems and symptoms during the last 3 months, atopy, smoking habits and working conditions. Serum samples were taken from 12 workers from offices where microbial measurements were conducted. Enzyme-linked immunosorbent assay (ELISA) was used to analyse microbe specific IgG antibodies against 15 microbes selected according the results obtained from microbiological analyses.

## RESULTS

### Microbes

Concentrations of viable fungi in material samples taken from fine filters were 10<sup>4</sup>–10<sup>5</sup> cfu/g (Table 1). On the surfaces of ventilation ducts, fungal concentrations were low (0–11 cfu/cm<sup>2</sup>). In offices, concentrations of airborne fungi were 0–21 cfu/m<sup>3</sup> and surface samples had scarce (ventilation system C) or abundant fungal flora (ventilation system A) (Table 1).

**Table 1** Microbes in material, surface and air samples on the service areas of four ventilation systems (A, B, C and D). Relative scale of surface samples analysed by direct plating (– = no growth, + = scarce, ++ = moderate, +++ = abundant, +++++ = very abundant growth)

| Ventilation system/sampling site  | n  | Mesophilic fungi |         |         | Mesophilic bacteria | Thermotolerant fungi |
|-----------------------------------|----|------------------|---------|---------|---------------------|----------------------|
|                                   |    | Hagem            | DG18    | M2      | THG                 | M2                   |
| Outdoor air (cfu/m <sup>3</sup> ) | 1  | 63               | 64      |         | 200                 |                      |
| A Fine filter (cfu/g)             | 1  | 26 200           | 21 700  |         | 18 000              | 30 000               |
| Air duct (cfu/cm <sup>2</sup> )   | 4  | 0–2              | 0–2     |         | 1–4                 |                      |
| Supply air (cfu/m <sup>3</sup> )  | 1  | 28               | 46      |         | 80                  |                      |
| Office air (cfu/m <sup>3</sup> )  | 1  | 6                | 7       |         | 66                  |                      |
| Surface of office                 | 1  | +++              | +++     | +++     | +                   |                      |
| B Fine filter (cfu/g)             | 1  | 72 700           | 55 300  |         | 51 000              | 7000                 |
| Air duct (cfu/cm <sup>2</sup> )   | 11 | 0–5              | 0–3     |         | 0–4                 |                      |
| Supply air (cfu/m <sup>3</sup> )  | 3  | 0–56             | 2–47    |         | 35–68               |                      |
| Office air (cfu/m <sup>3</sup> )  | 5  | 2–12             | 0–16    |         | 26–87               |                      |
| Surface of office                 | 5  | + to ++          | + to ++ | + to ++ | + to +++            |                      |
| C Fine filter (cfu/g)             | 1  | 40 800           | 290 900 |         | 36 900              | 25 500               |
| Air duct (cfu/cm <sup>2</sup> )   | 4  | 2–11             | 0–10    |         | 0–3                 |                      |
| Supply air (cfu/m <sup>3</sup> )  | 1  | 7                | 23      |         | 45                  |                      |
| Office air (cfu/m <sup>3</sup> )  | 4  | 5–12             | 2–21    |         | 54–177              |                      |
| Surface of office                 | 3  | +                | +       | +       | ++                  |                      |
| D Fine filter (cfu/g)             | 1  | 16 3000          | 135 500 |         | 46 400              | 2000                 |
| Air duct (cfu/cm <sup>2</sup> )   | 4  | 0–4              | 0–3     |         | 0–1                 |                      |
| Supply air (cfu/m <sup>3</sup> )  | 1  | 6                | 6       |         | 54                  |                      |
| Office air (cfu/m <sup>3</sup> )  | 1  | 7                | 6       |         | 132                 |                      |
| Surface of office                 | 1  | ++               | ++      | ++      | +                   |                      |

The occurrence of microbes in different samples taken from the service area of each ventilation system is presented in Table 2. The biodiversity of samples was high including, e.g. *Aspergillus fumigatus*, *Aspergillus versicolor*, *Acremonium*, *Aureobasidium*, *Chaetomium*, *Chrysosporium*, *Mucor*, *Paecilomyces*, *Rhodotorula*, *Trichoderma* and *Ulocladium*.

Sample taken from outdoor air contained *A. versicolor*, which was, however, found only from fine filter of one ventilation system.

**Table 2** The occurrence of microbes on the samples taken from service areas of four ventilation systems (A, B, C and D)

| Microbes                   | Sampling site     |                      |                       |                        |                      |
|----------------------------|-------------------|----------------------|-----------------------|------------------------|----------------------|
|                            | Filter<br>(n = 4) | Air duct<br>(n = 23) | Supply air<br>(n = 6) | Office air<br>(n = 11) | Surfaces<br>(n = 10) |
| <i>Alternaria</i> •        | –                 | –                    | A                     | –                      | AB                   |
| <i>Aspergillus (A.)</i> •  | AC                | BC                   | B                     | C                      | AC                   |
| <i>A. fumigatus</i> *      | ABCD              | D                    | –                     | B                      | –                    |
| <i>A. niger</i>            | B                 | C                    | B                     | –                      | CD                   |
| <i>A. penicillioides</i> * | –                 | –                    | –                     | C                      | –                    |
| <i>A. ochraceus</i> *      | –                 | –                    | –                     | –                      | AB                   |
| <i>A. versicolor</i> •*    | B                 | CD                   | C                     | ABC                    | ACD                  |
| <i>Acremonium</i> *        | A                 | –                    | –                     | –                      | –                    |
| <i>Aureobasidium</i> *     | ABD               | –                    | AC                    | BC                     | ABC                  |
| <i>Chaetomium</i> *        | –                 | ACD                  | –                     | –                      | A                    |
| <i>Chrysonilia</i> *       | CD                | –                    | –                     | –                      | –                    |
| <i>Cladosporium</i> •      | ABCD              | BCD                  | ACD                   | AC                     | ABCD                 |
| <i>Eurotium</i> •*         | A                 | –                    | –                     | B                      | BC                   |
| <i>Exophiala</i> *         | –                 | –                    | –                     | –                      | B                    |
| <i>Fusarium</i> *          | –                 | –                    | D                     | –                      | –                    |
| <i>Geomyces</i> *          | –                 | –                    | –                     | BC                     | –                    |
| <i>Geotrichum</i> •        | ABC               | –                    | –                     | A                      | –                    |
| <i>Mucor</i> *             | C                 | B                    | –                     | –                      | C                    |
| <i>Oidiodendron</i> *      | –                 | A                    | –                     | –                      | –                    |
| <i>Paecilomyces</i> *      | B                 | C                    | D                     | –                      | D                    |
| <i>Penicillium</i> •       | ABCD              | BCD                  | BCD                   | BCD                    | ABCD                 |
| <i>Rhizopus</i> *          | –                 | –                    | –                     | –                      | D                    |
| <i>Rhodotorula</i> *       | D                 | B                    | –                     | –                      | B                    |
| <i>Scopulariopsis</i> *    | –                 | –                    | –                     | –                      | B                    |
| <i>Sphaeropsidales</i> *   | –                 | –                    | A                     | –                      | –                    |
| <i>Streptomyces</i> *      | C                 | –                    | –                     | B                      | B                    |
| <i>Trichoderma</i> *       | –                 | C                    | –                     | B                      | B                    |
| <i>Tritirachium</i> *      | –                 | –                    | –                     | C                      | –                    |
| <i>Ulocladium</i> *        | –                 | AD                   | –                     | –                      | AB                   |
| Yeasts•                    | ABCD              | ABCD                 | ABCD                  | CD                     | ABCD                 |
| <i>Verticicladium</i>      | –                 | –                    | –                     | –                      | A                    |
| <i>Wallemia</i> *          | –                 | –                    | –                     | D                      | –                    |

• In outdoor air sample (n = 1) taken on roof terrace of 8th floor, \* indicator organisms.

### Symptom Survey

One hundred and seventy-three employees participated in the survey (response rate 58%). Complaints about work environment are presented in Table 3. Stuffy and dry air was perceived as a problem by more than 40% of respondents working on service area of all the ventilation systems. Unpleasant odor, dust and dirt were also common problems. Workers from service area of ventilation system B reported less problems than workers from other areas.

**Table 3** Work environment complaints on service area of different ventilation systems

| Perceived problem    | Ventilation system |         |         |         |
|----------------------|--------------------|---------|---------|---------|
|                      | A                  | B       | D       | Other   |
|                      | N (%)              | n (%)   | n (%)   | n (%)   |
| Draught              | 0 (0)              | 6 (9)   | 5 (18)  | 7 (12)  |
| Too high temperature | 3 (13)             | 16 (25) | 2 (7)   | 9 (16)  |
| Varying temperature  | 2 (8)              | 4 (6)   | 1 (4)   | 3 (5)   |
| Too low temperature  | 1 (4)              | 1 (2)   | 3 (11)  | 3 (5)   |
| Stuffy air           | 15 (63)            | 27 (42) | 13 (46) | 30 (53) |
| Dry air              | 13 (54)            | 29 (45) | 14 (50) | 24 (42) |
| Unpleasant odor      | 10 (42)            | 19 (30) | 11 (39) | 15 (26) |
| Static electricity   | 1 (4)              | 1 (2)   | 3 (11)  | 4 (7)   |
| Passive smoking      | 0 (0)              | 5 (8)   | 0 (0)   | 1 (2)   |
| Noise                | 4 (17)             | 11 (17) | 5 (18)  | 20 (35) |
| Dim light/glare      | 7 (29)             | 9 (14)  | 9 (32)  | 15 (26) |
| Dust and dirt        | 14 (58)            | 24 (38) | 9 (32)  | 31 (54) |

Work-related symptoms perceived weekly are presented in Table 4. Fatigue was common (perceived by more than 20% of workers) on service areas of all ventilation systems. Irritation symptoms of upper respiratory tract and eyes were common on service areas of ventilation systems A and D. Headache was a typical symptom related to ventilation system D.

**Table 4** Weekly symptoms on service area of different ventilation systems

| Symptom                       | Ventilation system |         |         |         |
|-------------------------------|--------------------|---------|---------|---------|
|                               | A                  | B       | D       | Other   |
|                               | n (%)              | n (%)   | n (%)   | n (%)   |
| Fatigue                       | 7 (29)             | 13 (20) | 10 (36) | 17 (30) |
| Head feels heavy              | 5 (21)             | 10 (16) | 3 (11)  | 12 (21) |
| Headache                      | 3 (13)             | 7 (11)  | 6 (21)  | 5 (9)   |
| Nausea/dizziness              | 3 (13)             | 2 (3)   | 1 (4)   | 3 (5)   |
| Difficulties in concentrating | 4 (17)             | 5 (8)   | 4 (14)  | 6 (11)  |
| Eye irritation                | 5 (21)             | 12 (19) | 6 (21)  | 20 (35) |
| Stuffy or runny nose          | 7 (29)             | 12 (19) | 7 (25)  | 18 (32) |
| Hoarse/dry throat             | 6 (25)             | 11 (17) | 7 (25)  | 10 (18) |
| Cough                         | 3 (13)             | 4 (6)   | 5 (18)  | 5 (9)   |
| Dry or flushed facial skin    | 3 (13)             | 7 (11)  | 3 (11)  | 10 (18) |
| Scaling/itching scalp or ears | 1 (4)              | 4 (6)   | 3 (11)  | 8 (14)  |
| Dry/itching/red skin of hands | 3 (13)             | 8 (13)  | 5 (18)  | 11 (19) |

More than 50% of workers had IgG antibodies to following microbes: *Aspergillus (A.) fumigatus*, *A. umbrosus* (=Eurotium), *A. versicolor*, *Aureobasidium pullulans*, *Fusarium avenaceum*, *Paecilomyces varioti*, *Penicillium brevicompactum*, *Phoma macrostoma*, *Rhodotorula glutinis* and *Trichoderma (T.) viride*.

Workers from service area of ventilation system A had antibodies on an average for 13 microbes, those of ventilation system B for 8 microbes, and those of ventilation system C and D for 10 microbes, respectively.

### DISCUSSION

Concentrations of viable fungi in the material samples taken from fine filters were  $10^4$ – $10^5$  cfu/g, which are typical concentrations in fine filters in Finland (Kokotti *et al.*, 2002; Halonen *et al.*, 2002). On the surfaces of ventilation ducts, fungal concentrations were low (0–11 cfu/cm<sup>2</sup>). In offices, concentrations of airborne fungi were 0–21 cfu/m<sup>3</sup> and surface samples had scarce (ventilation system C) or abundant fungal flora (ventilation system A).

The biodiversity of microbes in different samples taken from the service area of each ventilation system was high including, e.g. *Aspergillus fumigatus*, *Aspergillus versicolor*, *Acremonium*, *Aureobasidium*, *Chaetomium*, *Chrysosilia*, *Mucor*, *Paecilomyces*, *Rhodotorula*, *Trichoderma* and *Ulocladium*. High biodiversity is characteristic of moisture problems (Reiman *et al.*, 2002). In this particular case, *A. versicolor* found from outdoor air, fine filter of only one ventilation system and in offices might be originally migrated from damaged construction. There are two possible sources of indicator organisms (The international workshop *Health Implications of Fungi in Indoor Environments*, 1994) in this building: ventilation system or moist outer wall structures.

The response rate of the symptom survey was low (58%), which may lead to the overrepresentation of symptoms.

Stuffy and dry air was perceived as a problem by more than 40% of respondents working on service area of all ventilation systems. The symptom triad, stuffy air, dry air and unpleasant odour is typically seen in moisture and mould damaged buildings. This triad was seen in all studied areas. Dust and dirt were also common problems, which may be due to heavy traffic in the neighbourhood or to insufficient cleaning practices. Workers from service area of ventilation system B reported less problems than workers from the other areas. Fatigue, irritation of eyes and upper respiratory system were common weekly perceived work-related symptoms among the employees working in study areas A and D. Headache was a typical symptom related to ventilation system D. Causes of indoor air problems cannot be resolved by complaints and symptoms. However, the results of this survey suggest moisture and mould problems on service areas of ventilation systems A and D.

Workers had IgG antibodies against 10 microbes suggesting a common microbial exposure environment. Most of these microbes were found in the samples taken from the ventilation systems, which suggests at microbial exposure via supply air. *A. versicolor* and *T. viride* occurred mostly in other samples referring to another internal source. Workers' antibody findings are parallel with symptoms. Positive antibody results refer to microbial exposure from ventilation system or from moisture damaged constructions.

### CONCLUSION AND IMPLICATIONS

Microbial findings, IgG antibodies, complaints and symptoms indicate moisture and mould problems of the building.

Combined information obtained from microbiological research, immunological analyses and complaint and symptom surveys strengthens the accuracy of judgement concerning the nature of the problems in the building.

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