

# Viable fungi in indoor air in homes and schools in the Sør-Varanger community during winter

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The present study investigated the content of fungal aerospores in homes and schools of house-dust-mite (HDM)-sensitized and control children in a subarctic area. During winter, airborne microfungi were collected from the homes and schools of 19 HDM-sensitized children and 19 nonatopic controls, all living in the community of Sør-Varanger, northern Norway. The samples were cultivated and microfungal growth was identified microscopically. Indoor humidity, temperature, and carbon dioxide (CO<sub>2</sub>) concentrations were measured. Housing conditions and sociodemographic and symptom data were obtained by a questionnaire. *Penicillium* was the most common microfungus in both homes and schools, followed by various yeasts, *Aspergillus*, *Cladosporium*, and *Mucor*. The number of infected homes was equal in the HDM-sensitized group and the control group, but aerospore counts were higher in the HDM-sensitized group than in the control group. The lowest aerospore counts were found in the schools. High aerospore counts also appeared to be related to high indoor humidity. The keeping of pets and damp indoor conditions were more frequent in homes of HDM-sensitized children than in the control group, whereas parental smoking and carpeting occurred with equal frequency in both groups. This indicates that no allergy sanitation measures had been undertaken, especially in the homes of the HDM-sensitized children.

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We are exposed to many antigens outdoors and indoors that may give rise to allergic reactions (1–6). Whereas outdoor antigens are mainly determined by climatic and local factors (1, 7–9), exposure to at least some indoor allergens can be prevented through action by the residents themselves (1, 2, 5, 10, 11).

The indoor occurrence of spores largely reflects that of the outdoor air (7, 12–14), but dampness and damp building materials may provide suitable conditions for indoor fungal growth (2, 5, 7, 9, 15–17). The contribution of such growth to atopic sensitization and to the precipitation of allergic symptoms is mainly unknown. Epidemiologic studies from many Western countries indicate an increase in the prevalence of atopic diseases (18, 19). Outdoor as well as indoor environmental factors are believed to be possible causes (1, 2, 5, 18–20). Inadequate ventilation, which in cold climates can be a consequence of energy saving, may contribute to increased indoor humidity and house-dust mite (HDM) infestation (5, 21). The correlation of mite content with mould colony counts suggests that similar environmental con-

ditions, such as absolute indoor humidity (AIH), may influence the growth of both (5, 6). In previous studies (19, 22, 23), we have reported the possible influence of subarctic climate and environmental factors on the occurrence of atopic diseases and in particular the importance of domestic mites. The aim of this study was to investigate viable airborne microfungi in indoor air in homes and schools of children living in an area at 70° latitude N. Moreover, indoor environmental factors and living habits were related to the HDM-sensitized children and the control group.

## Material and methods

### Children and home environments

The study comprised 19 homes of HDM skin prick test (SPT)-positive children and 19 homes of nonatopic children acting as a control group and matched for age, sex, and residential area. All children were recruited from 424 clinically and SPT-tested schoolchildren aged 7–12 years in the community of Sør-Varanger, northern Norway (22, 23).

Sensitivity to cat dander was confirmed in 10, to dog dander in eight, to timothy pollen in five, to moulds in four, to birch pollen in two, to mugwort pollen in one, and to food in two of the 19 HDM-sensitized children. Questionnaires on the children's living conditions were given to their families and also to the school administration. People were asked about building techniques, basements, the age and state of repair, insulation, renovation, heating sources, humidifiers, air cleaners, cleaning frequency, pets, carpeting, family smoking habits, ventilation system and indications of dampness, condensation on window-panes, and previous water leaks. Special attention was given to exposure to allergens before the age of 2 years. Furthermore, all homes and schools were visited by one of the authors (L. K. Dotterud), and indoor temperature, humidity, and carbon dioxide (CO<sub>2</sub>) concentrations were measured when sampling was carried out.

#### Sampling areas

The investigation took place from January to March 1994 and comprised 38 homes and seven out of nine schools, including more than 90% of all schoolchildren in the community. The average outdoor temperature had been below 0°C for the last 3 months before sampling, and the ground had been covered by snow since the end of October 1993 and remained covered during the whole sampling period.

#### Sampling procedures

Microbial airborne particles were collected with a BIAP Slit-Sampler (8, 20) under normal living conditions, i.e., normal physical activity during the (break) day. Sampling and handling of the material concerning the microfungi were performed as described by Larsen (8). The BIAP Slit-Sampler was centrally placed about 1 m above the floor in the child's bedroom, the living-room, and classrooms. To prevent overloading of the agar surface, collections were made every 10 min, corresponding to 0.6 m<sup>3</sup> of sampled air (control measured by Mikrobiologiska och Biotekniska Testprodukter AB, Malmö, Sweden).

V-8 agar plates with penicillin and streptomycin were used for the cultivation of fungi (7). The agar plates were incubated for 4–6 days at 28°C, and fungal colonies were counted and identified by the Cotton blue-colour method (7, 8). When the identification was in doubt, the colonies were subcultivated for a total of 10 days. Microfungi were identified to genus level by macro- and microscopic appearance by standard taxonomic keys, as described by Gravesen (20) and Gravesen et al. (24), and results were given in total colonies/m<sup>3</sup> (col/m<sup>3</sup>) air. The follow-

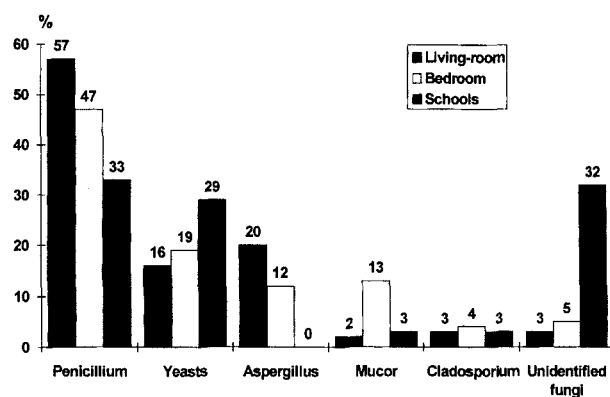


Fig. 1. Viable fungal genera identified (% occurrence) in 38 homes and seven schools.

ing fungal genera were identified: *Cladosporium*, *Alternaria*, *Penicillium*, *Mucor*, and *Aspergillus*. Other fungi were identified as yeasts or classified as unidentified. The indoor temperature and relative humidity were measured with the calibrated thermohygrometer (Therm 2250-1 No. 887944, Ahlborn Meß- und Regelungstechnik, Holzkirchen, Germany) and a standard swing psychrometer (S. Brannan and Son Ltd, Cleator Moor, Cumbria, UK), and converted to absolute indoor humidity with a Mollier diagram. The outdoor temperature and relative humidity were measured at Kirkenes Airport (local station, Norwegian Meteorological Institute). Only one CO<sub>2</sub> measurement was taken from living-rooms and classrooms with a Komyo gas detector AP-1 (Kitawaja) with 126 SD CO<sub>2</sub> gas-detector tubes. The recommended level of CO<sub>2</sub> is considered to be less than 1000 ppm (25).

#### Statistical methods

Concordance and discordance between the number of individuals in the various groups were evaluated with the chi-square test and the Fisher exact test. In addition, the odds ratio (OR) with a 95% confidence interval (95% CI) was calculated. If the 95% CI did not include 1.0, the results were statistically significant at  $P < 0.05$ . The correlation of spore counts between the HDM-sensitized group, the control group, and the schools was analysed by Spearman's rank correlation coefficient. The Wilcoxon (one- and two-sample) test was used to compare the different spore counts in the various groups.

## Results

#### Airborne fungal spores in homes

The five most common fungal genera from homes and schools are presented in Fig. 1. *Penicillium* was the most frequently occurring genus, and it also demonstrated the highest aerospore counts, account-

Table 1. Residential characteristics and living habits among 19 HDM-sensitized and 19 control children in community of Sør-Varanger. Odds ratio (OR) and confidence interval (CI) of 95% are also indicated

|                                                                     | HDM-sensitized group<br>(n = 19) | Control group<br>(n = 19) | OR        | 95% CI    |
|---------------------------------------------------------------------|----------------------------------|---------------------------|-----------|-----------|
| Aerospore counts $\geq 42$ (colonies/m <sup>3</sup> ) <sup>a)</sup> | 10                               | 9                         | 1.2       | 0.3–5.4   |
| Domestic mite infestation <sup>b)</sup>                             | 10                               | 0                         | $\geq 20$ | 2.0–487.7 |
| Water disaster(s) and/or damp patches                               | 8                                | 2                         | 6.2       | 0.9–52.2  |
| AIH $\geq 5.7$ (g/kg) <sup>c)</sup>                                 | 13                               | 10                        | 2.0       | 0.4–9.1   |
| CO <sub>2</sub> $\geq 1000$ ppm <sup>d)</sup>                       | 9                                | 8                         | 1.2       | 0.3–5.4   |
| Mechanical ventilation system                                       | 3                                | 2                         | 1.6       | 0.2–16.1  |
| Mucous irritation <sup>e)</sup>                                     | 10                               | 3                         | 5.9       | 1.1–37.0  |
| Frequent infections ( $\leq 2$ years)                               | 5                                | 4                         | 1.3       | 0.2–7.7   |
| House built or restored after 1970                                  | 15                               | 17                        | 0.44      | 0.1–3.5   |
| Wall-to-wall carpets                                                | 4                                | 5                         | 0.8       | 0.1–4.2   |
| Indoor smoking                                                      | 13                               | 12                        | 1.3       | 0.3–6.0   |
| Furred pets $\geq 1$                                                | 9                                | 6                         | 2.0       | 0.4–9.1   |

<sup>a)</sup> Mean aerospore counts = 42 colonies/m<sup>3</sup>.

<sup>b)</sup> Domestic mite infestation in mattresses identified by microscopy (21).

<sup>c)</sup> AIH mean value = 5.7 g/kg.

<sup>d)</sup> Normal CO<sub>2</sub> < 1000 ppm.

<sup>e)</sup> Symptoms of "dry" indoor air, eye and airway irritation.

ing for 50% of all spores, 57% of all spores in living-rooms, and 47% of all spores in bedrooms, followed by various yeasts, *Aspergillus*, *Cladosporium*, and *Mucor* (Fig. 1). *Penicillium* was identified in 34 homes, followed by various yeasts in 24 of the 38 homes. *Cladosporium* occurred in half of the homes, whereas both *Aspergillus* and *Mucor* were identified in seven of the 38 homes. Low aerospore counts of unidentified fungi were found in 22 homes. Surprisingly, *Alternaria* was not found at all.

More fungal spores were found in samples from living-rooms than bedrooms; however, the difference did not reach statistical significance (Fig. 1). No sample contained all the fungal genera, and all but one sample (from a bedroom) contained viable fungal spores. Small numbers of unidentified airborne fungal spores accounted for 2.9% and 5.0% of the total fungal spores in living-rooms and bedrooms, respectively. Various aerospores were found as frequently in homes of the control group as in those of HDM-sensitized children. Tables 1 and 2 show residential characteristics, housing factors, and living habits in HDM-sensitized and control children. Most samples contained low counts of aerospores; however, dust samples belonging to the HDM-sensitized group contained a large number of aerospores (Fig. 2). In all these homes, poor ventilation and/or other signs of poor indoor environmental conditions were found (such as increased AIH and/or CO<sub>2</sub>, mite infestation, and damp patches). A correlation was found between the number of aerospores in the bedroom and living-room in each home; i.e., a high count of aerospores in the living-room was equivalent to a high count of aerospores in the bedroom (in the HDM-sensitized group,  $r = 0.52$  ( $P < 0.03$ ); in the control group,  $r = 0.53$  ( $P < 0.02$ ).

There were no indications of any special sanitation measures in the homes, particularly not in the homes of the HDM-sensitized children. The reported cleaning habits did not differ between the two groups either. The mean AIH was found to be 5.7 (range 0–11.5) g/kg, slightly higher in living-rooms (6.1; range 0.3–11.5) than in bedrooms (5.3; range 0–10.8). An AIH of  $\geq 7.0$  g/kg was measured in 60% (23/38) of the homes (19 living-rooms and 17 bedrooms).

Mucous irritation was reported significantly more frequently in HDM-sensitized children than in controls. Signs of poor ventilation, i.e., damp patches and recent or previous water leaks, were more fre-

Table 2. Residential characteristics and housing factors in 38 homes of schoolchildren in community of Sør-Varanger

|                                                | n = 38 |
|------------------------------------------------|--------|
| Residential characteristics                    |        |
| Detached houses                                | 32     |
| Mineral-wool thermal insulation                | 37     |
| Smooth floors with scatter rugs – living-rooms | 28     |
| – bedrooms                                     | 15     |
| Smooth walls – living-rooms                    | 28     |
| – bedrooms                                     | 32     |
| Furniture – living-rooms (normal)              | 34     |
| – bedrooms (normal)                            | 32     |
| Ventilation systems                            |        |
| Mechanical ventilation system                  | 5      |
| Natural ventilation                            | 19     |
| Window frame ventilation                       | 14     |
| Appliances                                     |        |
| Humidifiers                                    | 6      |
| Air cleaners                                   | 3      |
| Drier                                          | 18     |
| Heating systems                                |        |
| Oil                                            | 1      |
| Electric                                       | 8      |
| Combination <sup>a)</sup>                      | 29     |

<sup>a)</sup> Combinations of wood, oil, and electric heating.

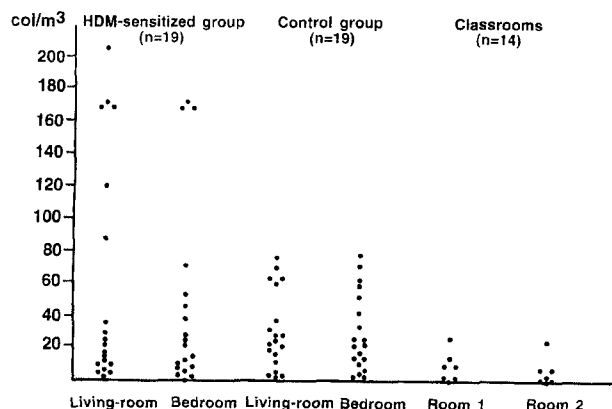


Fig. 2. Distribution of total fungi in air samples from 38 homes of HDM-sensitized and control children and from 14 classrooms in seven schools.

quently found in homes of HDM-sensitized children than in controls (Table 1). The total fungal aerospore counts were found to be higher in homes with  $\text{AIH} \geq 5.7$  g/kg than with  $\text{AIH} < 5.7$  g/kg ( $P < 0.05$ ). Moreover, an inverse correlation was found between mechanical ventilation and indoor humidity ( $P < 0.005$ ). Increased  $\text{CO}_2$  levels were found in 17 (45%) of the 38 living-rooms, and high  $\text{CO}_2$  levels were correlated with increased AIH ( $P < 0.05$ ).

#### Airborne fungal spores in schools

Only small numbers of aerospores were found in the classrooms (Fig. 1). In one of the seven schools, no fungal spores could be found in the two classrooms selected for sampling. Moreover, in the classrooms, *Penicillium* was the most frequently occurring genus with the highest aerospore counts, followed by yeasts (Fig. 1). *Mucor* and *Cladosporium* were found in very small numbers, whereas *Aspergillus* and *Alternaria* were absent, even in the library where the floor was carpeted (Fig. 1).

All schools had a low AIH (average  $-2.4$  g/kg) and a low relative indoor humidity (14–39%) with a temperature range of 19–24°C. Two of the seven schools had an inadequate central ventilation system; i.e., the  $\text{CO}_2$  levels were above the upper limit. However, no increased occurrence of fungal aerospores was found in these schools. All but one room had smooth floors.

Nevertheless, low levels of aerospores were found in all classrooms ( $r = 0.92$ ;  $P < 0.005$ ). Significantly higher numbers of microfungi were found in both the HDM-sensitized group and control group homes than in the schools ( $P < 0.01$ ) (Fig. 2).

#### Discussion

As far as we know, there has never been a study of airborne fungi as a cause of allergic disease in a sub-arctic region.

In this study, we found the same fungal species that have been reported in other parts of northern Europe (5, 7, 11, 24).

*Penicillium* was the fungal genus most frequently found, in accordance with other studies (5, 7, 11, 12, 17). On the other hand, and in contrast to previous studies, *Cladosporium* was found sparsely and in only half of the homes (7, 11, 15, 20, 26). Surprisingly, *Alternaria*, which is often reported to be one of the main indoor as well as outdoor fungi, was absent in all samples (5–9, 15, 20, 25, 26). However, *Cladosporium* and *Aspergillus* have been found in large numbers ( $>10\,000$  spores/ $\text{m}^3$  air) outdoors, and even small numbers of *Alternaria* and other viable fungi have been detected during warm summers in northern Norway (H. J. Høeg, personal communication). Although seasonal variations occur, a sub-arctic climate means few fungal spores and a short period of sensitization, except for *Penicillium*, which is a “year-round” mould (1, 8, 20, 27). Although the sample size was small, we believe that these results represent indoor fungal growth in this area.

The investigations were performed in the winter during a period of subzero outdoor temperatures with the ground extensively covered by snow; thus, direct contribution from outdoor aerospores was minimized (5). However, the possibility of influx of outdoor mould spores brought into the buildings during summer cannot be completely ruled out (9, 28). The fungal genera found in indoor air were not simply a reflection of the viable aerospores reported in outdoor air during warm summers in northern Norway. Thus, the fungal genera found in indoor air are supposed to represent indoor fungal growth, and not to have been trapped in a poorly ventilated home (9, 11, 20). This was a prerequisite for the study and the attempt to correlate indoor fungal exposure to other indoor environmental factors. Some fungi, e.g., *Mucor*, are more often found in floor dust and carpets than in air samples (6, 8, 20, 24, 27). Our findings of small numbers of aerospores do not exclude the possibility of larger numbers being present in floor dust (20, 27).

A relationship was found between damp housing and increased occurrence of microfungi. Damp patches and/or water leaks and the presence of HDM in mattress dust were more frequent in the homes of the HDM-sensitized group (21). These observations suggest that indoor fungal growth is often a result of construction faults in the house, such as poor ventilation, increased AIH, and inadequate cleaning (1, 2, 5, 9, 10, 16, 17). The high  $\text{CO}_2$  levels found in homes may be a further indicator of poor indoor climate (25, 28). The failure to find a significant difference between the HDM-sensitized group and the control group in reported cleaning habits

and sanitation measures is probably attributable to the parents' ignorance of the importance of allergy sanitation (19, 23). This suggestion is also supported by the frequent keeping of pets and parental smoking in both groups, which also indicate lack of allergen sanitation measures, even if these findings do not necessarily have implications for the general cleaning habits.

The children's unusually low sensitivity to moulds and mites is probably attributable to the low occurrence of these allergens in this area (21, 23). Standardized and commercially available allergen extracts are widely used and are supposed to be of adequate potency (29). This is confirmed by the children's frequent positive reactions to allergens other than mites and moulds (23). Mucous irritation, which is more frequently reported in HDM-sensitized than in control children, can probably be explained by the fact that 15 of the 19 children had various symptoms of atopic diseases.

As the HDM-sensitized group more frequently demonstrated other signs of living in poorly ventilated homes than the control group and frequently exhibited increased AIH, we hypothesized that dampness and insufficiently ventilated homes could contribute to the higher aerospore counts found in the HDM-sensitized group. In contrast to Dybendal Elsayed (30), we found significantly lower aerospore counts in schools than in homes, and this may be the result of good indoor climate and good sanitary conditions in schools (10, 16, 17, 26, 31). None of the schools showed any evidence of dampness, such as visible mould spots, damp patches, or window condensation, and the AIH was low. Moreover, one-third of the few aerospores found in the classrooms belonged to the unidentified fungi.

We conclude that generally low aerospore counts were found, except in some homes of HDM-sensitized children. Low microfungi counts in homes and schools confirm a recent finding of low RAST inhibition values for *Cladosporium* in dust samples from the same homes and schools (32.) The importance of allergen sanitation measures has to be communicated to predisposed subjects to reduce the risk of developing atopy, although the health implication of the occurrence of indoor microfungi in this geographic region seems to be a minor problem.

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