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Fungal species in mold-damaged and nondamaged office buildings in southern Finland

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Objectives In this study, the prevalence of typical fungal species in modern, nonmoisture-damaged offices was compared with the prevalence of fungi in moisture- and mold-damaged office buildings.
Methods The study included 34 mold-damaged and 43 nondamaged office buildings in southern Finland. Most of the buildings had a concrete structure and several floors. A mechanical ventilation system was in use in 86% of the buildings. Wintertime samples of indoor air, settled dust, and building material were collected from the buildings.
Results *Penicillium* was the most prevalent fungi in the environmental samples studied. Still, the prevalence of *Penicillium* and *Aspergillus versicolor* gave the strongest indication of mold damage in the buildings studied (P-value <0.001 or <0.01), although all the fungi examined were identified in both the damaged and nondamaged buildings. Other predominant fungi in the office buildings were yeasts, sterile fungi, and *Cladosporium.* Some indicator value for mold damage was associated with the prevalence of *Aspergillus fumigatus, Aspergillus niger, Aspergillus ochraceus, Aspergillus glaucus, Acremonium, Paecilomyces variotii, Rhizopus stolonifer,* and *Stachybotrys chartarum*.
Conclusions This study shows that workers are more exposed to *Penicillium* species than to other species in office environments regardless of whether mold damage is present or not. It also shows that moisture indicators are not absolutely specific.

Key terms office environment.

Fungi are ubiquitously present in both indoor and outdoor environments (1). Fungal spores grow easily on moist substrates, and, in a building, this growth is associated with moisture damage (2). Furthermore, exposure to airborne fungal spores may cause health disorders and symptoms. A typical range of fungal species in residential buildings has been published, revealing that some fungi are associated with moisture and mold damage in buildings (3–4). However, comparable information for office environments is almost nonexistent, especially in a subartic climate. In this study, we determined the prevalence of typical fungal species in modern, nonmoisture-damaged offices and of fungi associated with moisture- and mold-damaged office buildings. An evaluation of indoor-air quality was also made to determine any abnormal fungal sources in the offices and to assess workers' exposure to fungi in office environments.

Material and methods

Our study included 34 mold-damaged and 43 nondamaged office buildings in southern Finland. The investigations were performed by specialists from the Finnish Institute of Occupational Health. Experienced construction engineers carried out inspections for damage caused by moisture and mold. An inspection included interviewing building maintenance and management personnel and workers, a survey of the construction drawings, inspection for signs of moisture and mold, and the opening of

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the structure if needed. Microbial growth in structures was verified mostly with microbial analyses.

The buildings represented the typical Finnish urban style of construction; most of them had a concrete framework and several floors. The mechanical ventilation system was in use in 86% of the buildings, while the remaining had either an exhaust-air system or natural ventilation. Indoor air samples (102 samples) taken with a six-stage cascade impactor (Andrersen 10-800, Graseby Andersen, Atlanta, GA, USA), settled dust (173 samples), and building material (70 samples) were collected from the buildings during a period from November to March between 2001 and 2005. Air samples were taken during the day during the normal work activities in the work area at the height of approximately 1.5 meters. The fungi were cultured on 2% malt extract agar and 18-dichloran-glyserol agar and then incubated at 25°C for 7 days. An experienced microbiologist identified fungi according to genus, species or its type level using a light microscope. The concentrations of fungi were expressed as colony-forming units per gram (cfu/g) for the material samples and as colony-forming units per cubic meter (cfu/m^3) for the air samples. The results of the settled dust samples were expressed on a semi-quantitative scale as follows: + = 1–9 cfu/100 cm^2; ++ = 10–49 cfu/100 cm^2; and +++ = >49 cfu/100 cm^2.

Results

The most prevalent fungi detected in the environmental samples from the mold-damaged and control office buildings are presented in the tables 1 and 2. The prevalence of *Penicillium* and *Aspergillus versicolor* were the strongest indicators of mold damage in the studied buildings (P-value <0.001 or <0.01) even though all of these fungi were identified in both the damaged and non-damaged buildings. Fungi that were less prevalent in the data (about 5–10% of the samples) but still associated with mold damage (P<0.01) were *Aspergillus fumigatus, Aspergillus niger, Acremonium, Paecilomyces variotii,* and *Rhizopus stolonifer*. The airborne concentrations of fungi were relatively low, but somewhat higher in the mold-damaged office buildings than in the control buildings. The geometric mean of the concentrations of individual fungal species was ≤4 cfu/m^3 for the control offices and ≤22 cfu/m^3 for the offices with mold damage. The predominant fungi in settled dust were the same (*Penicillium, yeasts,* sterile fungi, and *Cladosporium*) in both the mold-damaged and nondamaged offices, but semi-quantitative levels were higher in the mold-damaged offices. *Aspergillus ochraceus, Aspergillus glaucus,* and *Stachybotrys chartarum* were found only in the environmental samples collected from the mold-damaged buildings. The prevalence of the species of fungi in the material samples correlated well with the fungi in the air and in the settled dust samples, with the exception of *Acremonium*, which was more abundant in damaged materials.

Discussion

This study shows that workers are more exposed to *Penicillium* species than to other species in office environments regardless of whether mold damage exists or not. However, elevated concentrations of *Penicillium* were associated with mold damage in building constructions. In this study, *Penicillium* was analyzed only on the genus level, and therefore the findings contain several species of *Penicillium*. It is probable that the *Penicillium* species may be somewhat different in mold-damaged and

Table 1. Most common fungi (in order of prevalence) in the indoor air samples from mold-damaged and nonmold-damaged office buildings. (MEA = 2% malt extract agar, DG18 = 18-dichloran-glyserol agar, cfu = colony-forming units)

Fungi	Indoor air samples			
	Mold-damaged offices (N=46)		Nonmold-damaged offices (N=56)	
	MEA[a]	DG18[a]	MEA[a]	DG18[a]
Penicillium	9	11	4	5
Sterile fungi	6	7	4	3
Cladosporium	7	6	2	3
Yeasts (several species)	3–6	2–5	2	2–3
Aspergillus versicolor	13	9	5	2

[a] Geometric mean (cfu/m^3).

Table 2. Most prevalent fungi (% of the samples) in material and settled dust samples from mold-damaged and nondamaged office buildings. (MEA = 2% malt extract agar and DG18 = 18-dichloran-glyserol agar)

Fungi	Material samples		Settled dust sample			
	Mold-damaged offices (N=70)		Mold-damaged offices (N=47)		Nonmold-damaged offices (N=126)	
	MEA (%)	DG18 (%)	MEA (%)	DG18 (%)	MEA (%)	DG18 (%)
Penicillium	61	60	49	55	18	23
Aspergillus versicolor	26	31	13	13	5	3
Yeasts (several species)	20	17	19–30	6–36	..	..
Cladosporium	..	..	..	..	15	17
Acremonium	24	14	..	..	..	..
Sterile fungi	..	..	19	23	0	14
Aspergillus sydowii	17	23	..	..	..	..
Cladosporium	..	..	15	21	..	..
Alternaria	..	..	..	..	2	5

nondamaged buildings. Further research with molecular biology methods (eg, polymerase chain reaction) may help to determine whether they do or not.

Fungi that require water activity (a_w) above 0.85 to grow have been regarded as indicator organisms for moisture problems (5). These fungi include, among others, *Trichoderma, Exophiala, Phialophora, Ulocladium, Stachybotrys, Fusarium, Wallemia, A versicolor, A fumigatus,* and yeasts. The moisture indicator fungi were detected more often in the mold-damaged offices than in the nondamaged offices. Our study shows, however, that moisture indicators are not absolutely specific. Low concentrations of many moisture indicators can also be found in buildings with no mold damage. Some indicator value for mold damage was associated with the prevalence of *A fumigatus, A niger, A ochraceus, A glaucus, Acremonium, Paecilomyces variotii, Rhizopus stolonifer,* and *S chartarium*.

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