Building-related microbes before and after the repair of moisture damage

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ABSTRACT

In two school buildings, concentrations of viable fungal spores in air, material and in surface samples were high indicating moisture and mould damages. Microbes included numerous moisture indicating species (e.g. *Aspergillus versicolor*, *Trichoderma*, *Fusarium*, *Stachybotrys*, *Chaetomium*, *Streptomyces*). After renovation, the school buildings were thoroughly cleaned. Surfaces still had abundant and diversiform microflora. After repeated cleaning, abundance and diversity of microflora diminished. According to this study, moisture damages have great influence on the microbiology of the building increasing the concentrations and diversity of microbes. The renovation of major damages causes declining of microbial counts and species, but leaves the traces of indicator microbes to the building. Repeated cleaning normalizes the microbiology of the building. Normal use of the building returns the diversity of microflora, but the concentrations remain low, which is unlike the situation before the repair.

INDEX TERMS

Moisture damage; Building; Renovation; Cleaning; Microbial contamination

INTRODUCTION

Several factors including the construction of the building, incorrect use of building materials, insufficient ventilation, water leakages, lack of covered drains and even the use of excess water in cleaning (Kujanpää *et al.*, 2002) may cause moisture and mould problems of the buildings. Microbiological methods are used as a tool in indicating mould problems, in evaluating the quality of repair and efficiency of cleaning. Moisture indicating microbes (The International Workshop *Health Implications of Fungi in Indoor Environments,* 1994) are characteristic of buildings with moisture problems. In some cases, indicator microbes have been found in high concentrations in repaired buildings, if the repairs have not been sufficient enough (Kokotti *et al*., 1999), or cleaning practices after repair have been inadequate (Hung, 1999). The aim of the present study was to evaluate how the renovation and successive cleaning affect the microbiology of the building.

MATERIAL AND METHODS

Our study included two school buildings with frames made of concrete and brick. Both schools had had leaking roofs and drains and damages caused by excess use of cleaning waters. Microbial problems were suspected according to sensory assessment. Before renovation, material, surface and air samples were taken to assess microbiology of each building. After renovation, surface samples were taken to

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evaluate the quality of repair and efficiency of cleaning. Surface sampling may be used to identify microbial diversity and the relative degree of biological contamination (Martyny *et al.*, 1999). We used direct plating, which gives more information of microbial genera than dilution plating (Hoekstra *et al*., 1994, Reiman *et al*., 1999, 2002). Mesophilic fungi were cultivated on malt-extract–Rose Bengal-agar (Hagem), dichloran–glycerol-agar (DG18), and 2% malt-extract-agar (M2) and mesophilic bacteria including actinobacteria on tryptone–yeast-extract–glucose-agar (TYG). The plates were incubated at +25±3°C for 7 days. Fungi were identified using common mycological procedures.

RESULTS

In connection with the inspection of building techniques, high concentrations of microbes were recovered from the material samples and surface samples (Table 1).

Table 1 Ranges of spore concentrations in samples taken before renovations. Figures have been extracted from the results from all fungal media (n= number of samples) (ND=not determined)

Sample type	School #1		School #2	
	n	Range	*n*	Range
Material (cfu/g)	7	8×10^4–6×10^6	51	<100 to 6×10^6
Surface, dilution plating (cfu/cm^2)	3	1–300	12	1–800
Surface, direct plating (cfu/plate)	–	ND	4	0–200
Air (cfu/m^3)	4	<800 to 4×10^6[a]	14	40–400[b]

[a]CAMNEA-method was used to take air samples from fitting socles.
[b]Andersen impactor was used to take air samples from indoor air.

Renovation and repeated thorough cleaning diminished colony counts on surfaces (Table 2). Normal use of school buildings increased microbial amounts on surfaces to some extent.

Table 2 Ranges of spore concentrations in surface samples (cfu/plate) taken after renovations. Figures have been extracted from the results from all fungal media (*n* = number of samples) (ND=not determined)

Time of sampling	School #1		School #2	
	n	Range	*n*	Range
After repair and cleaning by conventional methods	6	9 to >200	8	<1 to 22
After repair and all-out cleaning of the building with no users	4	<1 to 10	16	<1 to 16
After repair and all-out cleaning and 1.5 months' use of the building	15	<1 to 35	15	<1 to 24

Before renovations, microbes included great variety of moisture indicating species (e.g. *Aspergillus versicolor*, *Trichoderma*, *Fusarium*, *Stachybotrys*, *Chaetomium*, *Streptomyces*) i.e. high microbial diversity was found in the schools as shown in Table 3.

Table 3 The occurrence of different microbial taxa before and after repair (B = before repair, A1 = after repair and cleaning by conventional methods, A2 = after repair and all-out cleaning of the building with no users, A3 = after repair and all-out cleaning and couple of months' use of the building) (+, microbe was detected; –, microbe was not detected)

Microbe	School #1				School #2			
	B	A1	A2	A3	B	A1	A2	A3
Acremonium[a]	–	–	–	+	+	–	–	–
Alternaria	–	–	–	–	+	+	–	+
Aspergillus spp.	+	+	+	+	+	+	+	–
Aspergillus fumigatus[b]	–	–	–	–	+	+	–	–
Aspergillus niger	–	–	–	–	+	–	–	+
Aspergillus versicolor[b]	+	+	+	+	+	+	+	–
Aureobasidium[a]	+	–	–	+	+	–	+	+
Chaetomium[a]	+	+	+	+	+	–	–	–
Cladosporium	+	+	+	+	+	+	+	+
Eurotium[b]	+	–	–	–	+	–	+	+
Fusarium[b]	+	–	–	–	+	–	–	–
Geomyces[a]	–	–	–	–	+	–	–	+
Geotrichum	–	–	–	–	+	+	–	–
Yeasts[b]	+	+	–	+	+	+	–	+
Oidiodendron[a]	–	–	–	–	+	–	–	–
Paecilomyces[a]	+	+	–	–	+	+	–	–
Penicillium spp.	+	+	+	+	+	+	+	+
Phialophora[b]	+	–	–	–	–	–	–	–
Rhizopus[a]	–	–	–	+	–	–	–	–
Scopulariopsis[a]	+	–	–	–	+	–	–	–
Sphaeropsidales[a]	+	+	–	+	+	–	+	–
Sporobolomyces[b]	+	–	–	–	–	–	–	–
Stachybotrys[b]	+	–	–	+	+	–	+	–
Streptomyces[b]	+	+	–	–	+	+	–	+
Trichoderma[b]	+	+	–	–	+	+	+	+
Tritirachium[a]	–	–	–	–	+	–	–	–
Wallemia[a]	–	–	–	–	+	–	–	+
Number of taxa	17	10	4	11	24	11	9	11

[a]Indicator organisms based on the experience of laboratories of Finnish Institute of Occupational Health.
[b]Indicator organisms according to The International Workshop on *Health Implications of Fungi in Indoor Environments* (1994).

Fusarium, Oidiodendron, Phialophora, Scopulariopsis, Sporobolomyces and *Tritirachium* occurred only before the repair. Neither the repair nor the all-out cleaning was able to eliminate *Penicillium* spp. and *Cladosporium* in either of the schools, and *Chaetomium* and *Aspergillus versicolor* in school #1 and *Trichoderma* in school #2 (Table 3).

In school #1, four microbes reappeared after the building was taken up for use and in school #2, nine microbes.

DISCUSSION

Microbial concentrations and microflora in the two school buildings were typical of moisture damaged building (Samson, 1999; Kujanpää *et al*., 2002). In both the buildings, microbes included numerous moisture indicating species (e.g. *Aspergillus versicolor, Trichoderma, Fusarium, Stachybotrys, Chaetomium, Streptomyces*). Observations made during the technical inspection and microbiological findings led to renovations, which later proved to be insufficient.

Spreading of microbial propagules was not effectively prevented during the renovation in either of the schools. Because of this, especially microbes with dry spores (e.g. *Aspergillus* spp. and *Penicillium* spp., *Cladosporium* and *Paecilomyces*) (Burnett, 1976) were liberated and transferred onto surfaces. After renovation, the building was cleaned by conventional methods with no special effort focused on removal of fine dust including microbes. In addition to fungi with dry spores, several moisture-indicating microbes detected before could be found on surfaces. The most probable explanation for this is that the cleaning procedure after renovation had been insufficient as shown also in other studies (Hung, 1999). Kokotti *et al.* (2002) found that elimination of exceptional microflora after the repair of moisture-damaged building does not seem to succeed because spores migrate from external sources or settled ones re-suspend from surfaces.

After repeated cleaning, abundance and diversity of microflora diminished. After school #1 had been taken up for use, biodiversity increased, but microbial concentration remained low on surfaces. Increase of biodiversity may be due to normal use of the building (Lehtonen *et al*., 1993), which causes the re-suspension of settled dust. Microbes may also originate from outdoors, mould problem buildings (e.g. *Acremonium*) or other environments.

In school #2, every-day activities or external sources do not explain the reappearance of all microbes. Renovations covered only part of the constructional faults, which led to moisture and mould problems. For example, *Trichoderma, Streptomyces, Eurotium* and *Aureobasidium* are indicators of ongoing problems. Afterwards, there has been extensive and thorough renovation in this school.

CONCLUSION AND IMPLICATIONS

According this study, moisture damages have great influence on building related microbes increasing the concentrations and diversity of microbes.

The repair of major damages causes declining of microbial counts and diversity, but leaves small amounts of indicator microbes to the building.

Sufficient protection of constructions during repair work is needed to prevent spreading of microbes.

Repeated cleaning normalizes the microbiology of the building reducing especially the occurrence of indicators.

Normal use of the building returns the diversity of microflora, but the concentrations remain low, which is unlike the situation before the renovation.

Thorough repair of mould damages and subsequent effective cleaning are necessary actions in normalizing the microbiology of the building.

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