# SUFFICIENCY OF CLEANING AFTER REPAIR OF MOLD DAMAGE EVALUATED BY MICROBIOLOGICAL METHODS

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## ABSTRACT

Constructional aspects and the use of school building had led to moisture and mold damages confirmed by microbiological analysis from material, surface and air samples. Cultivation methods were used to assess mesophilic fungi and actinobacteria. High concentrations of microbes ($10^5$-$10^6$ cfu/g in different materials) were recovered from the samples. Microbes included great variety of moisture indicating species (e.g. *Aspergillus versicolor, Trichoderma, Fusarium, Stachybotrys, Chaetomium, Streptomyces*). The leaking roof of the building was repaired and all damaged materials were removed and replaced by new ones. Spreading of microbial propagules was not effectively prevented. Only part of the wet constructions were dried. After repair the building was cleaned by conventional methods with no special effort focused on removal of fine dust. Sufficiency of cleaning was evaluated by microbiological sampling from material surfaces having abudant and diversiform microflora. Thereafter the building was cleaned using techniques adapted for washing off mold dust. Two weeks after this cleaning, abundance and diversity of microflora had diminished. According this result, all-out cleaning is required to get rid of mold dust arisen during repair of moisture and mold damages in the building. After the building was taken in use, diversity of microflora returned but the concentrations remained low.

## KEYWORDS

Mold damage, repair, cleaning, microbes, cultivation methods, surface sampling.

## INTRODUCTION

The construction of the building, incorrect use of building materials, water leakages, lack of covered drains, and the use of excess water in cleaning (Kujanpää et al. 2002) are some of the several factors causing moisture and mold problems of the buildings. Microbial growth of the building is a common cause of indoor air complaints. Samples for microbiological analyses are taken from air, material surfaces, and building materials to indicate damage. In our country, great number of buildings are repaired every year because of water damages. Microbiological methods are used as a tool in evaluating the quality of repair. Moisture indicating microbes (The international workshop *Health Implications of Fungi in Indoor Environments,* 1994) have been found in high concentrations in repaired buildings (Hung 1999). In some cases, the repairments have not been sufficient enough (Kokotti *et al*. 1999), in other cases, cleaning practices after repair have been inadequate (Hung 1999). If people suffer from symptoms after repair of damages, attention should be paid to cleaning practices. In the present study, the aim was to evaluate the potential of microbiological methods in indicating the effectiveness of cleaning after the repair of mold damages.

## MATERIAL AND METHODS

The object of this study was a school building erected in 1967. The school is a 2-floor concrete and brick building with a pitched roof which was renovated in summer 1999. During the following fall, the building went through the inspection of building techniques. In this inspection, mold damages were recorded. The most probable reasons for these damages were the entry of rain water to unprotected concstructions during the roof renovation, earlier leakages of water pipes, and cleaning waters absorbed by constructions.

Samples for microbiological analyses were taken before and after renovation. Culturable microbes were determined from the samples. Mesophilic fungi were cultivated on malt-extract-Rose Bengal -agar (Hagem), dichloran-glycerol -agar (DG18), and 2 % malt-extract-agar (M2) and mesophilic bacteria on tryptone-yeast-extract-glucose -agar (TYG). The plates were incubated at +25°C for 7 days.

Air samples were taken onto polycarbonate filter from the cavity space of construction with a pump (air flow 4 l/min). Microbes were eluated for further 10-fold dilution. From each aliquot, 0.1 ml were plated onto the media. Results are expressed as colony forming units per $m^3$ of air (cfu/$m^3$). Material samples were taken from walls behind the base-boardings and from the inner surface of construction cavity. Material samples were analysed using dilution-plating method (Reiman *et al*. 1999); results are expressed as cfu/g. Surface samples were taken from 10x10$cm^2$ area of the surface by wiping with a sterile swab. In dilution plating method, samples were taken into buffer (Pasanen *et al*. 1992) for further ten-fold dilution. From each aliquot, 0.1 ml were plated onto the media. Results are expressed as colony forming units per $cm^2$ (cfu/$cm^2$). In direct plating method, sample wiped from the 100 $cm^2$ area was streaked by the cotton swab onto cultivation medium; results are expressed as cfu/plate (Reiman *et al*. 2002).

After the school building was repaired and cleaned, samples from vertical surfaces were taken for direct cultivation used for microbiological evaluation.

## RESULTS

In the samples taken in the connection of the inspection of building techniques, high concentrations of microbes were found. Air samples taken from the cavity spaces of construction had $10^4$-$10^6$ cfu/$m^3$ of viable fungal spores, mainly those of *Aspergillus versicolor, Penicillium*, and *Streptomyces*, and minor amounts of *Trichoderma* and *Fusarium*. High concentrations of microbes ($10^5$-$10^6$ cfu/g) were recovered from the material samples. Microbes included great variety of moisture indicating species (e.g. *Aspergillus versicolor, Trichoderma, Fusarium, Stachybotrys, Chaetomium, Streptomyces*). In addition, surface sampling revealed the presence of *Aureobasidium*. Viable spore concentrations of surface samples varied between 3-301 cfu/$cm^2$. Before repair, 17 different taxa were found in the samples indicating high microbial diversity as shown in Table 1.

After repair of the school building, sufficiency of cleaning was evaluated by microbiological sampling from material surfaces. Interior surfaces showed abudant (15->200 cfu/plate) and diversiform microflora including still 10 same taxa (Table 1). More than 50 % of the colonies with small colony counts were those of *Chaetomium* or other moisture indicating microbes.

Thereafter the building was cleaned using techniques especially adapted for washing off mold dust. Two weeks after this cleaning, abundance had diminished (1-10 cfu/plate) and diversity of microflora had reduced to 4 taxa (Table 1). Later diversity of microflora returned back to 11 taxa from which 9 taxa were the same as before the repair. The amount of microbes remained, however, low (0-28 cfu/plate) after the building was taken in use (Table 1). No viable fungal spores were found in 13 % (2/15) of the samples, and 67 % (10/15) of the samples had less than 10 colonies/plate. *Chaetomium* was still found in 73 % (11/15) of the samples.

TABLE 1
The occurrence of different microbial taxa before and after repair and successive episodes of cleaning (+= microbe was detected, -=microbes was not detected).

| Microbe | Inspection of building techniques before repair | After repair and cleaning by conventional methods | After repair and all-out cleaning of the building with no users | After repair and all-out cleaning and 1_ months' use of the building |
|---|---|---|---|---|
| *Acremonium*** | - | - | - | + |
| *Aspergillus spp.* | + | + | + | + |
| *Aspergillus versicolor** | + | + | + | + |
| *Aureobasidium*** | + | - | - | + |
| *Chaetomium*** | + | + | + | + |
| *Cladosporium* | + | + | - | + |
| *Eurotium** | + | - | - | - |
| *Fusarium** | + | - | - | - |
| Yeasts* | + | + | - | + |
| *Paecilomyces*** | + | + | - | - |
| *Penicillium spp.* | + | + | + | + |
| *Phialophora** | + | - | - | - |
| *Rhizopus*** | - | - | - | + |
| *Scopulariopsis*** | + | - | - | - |
| Sphaeropsidales** | + | + | - | + |
| *Sporobolomyces** | + | - | - | - |
| *Stachybotrys** | + | - | - | + |
| *Streptomyces** | + | + | - | - |
| *Trichoderma** | + | + | - | - |

*indicator organisms according to The international workshop *Health Implications of Fungi in Indoor Environments*, (1994)
** indicator organisms based on the experience of laboratories of Finnish Insitute of Occupational Health

*Eurotium, Fusarium, Phialophora, Scopulariopsis* and *Sporobolomyces* occurred only before the repair. *Cladosporium, Streptomyces* and *Trichoderma* were not detected after all-out cleaning. Neither the repair nor the all-out cleaning was able to eliminate *Aspergillus* spp (including *Aspergillus versicolor*), *Penicillium* spp and *Chaetomium* (Table 1).

*Acremonium* and *Rhizopus* were genera which appeared as new ones, and *Aureobasidium*, *Cladosporium*, Sphaeropsidales, yeasts and *Stachybotrys* were fungi which reappeared after the building was taken in use.

## DISCUSSION

There were several constructional reasons having led to moisture problems in the school building. As the first step of repair, the leaking roof of the building was repaired. During the roof repair occasional heavy rain showers wet unprotected constructions. This was the reason for further technical investigations in which connection high concentrations of moisture indicating species were found in the samples. Microflora and the amount of microbes were typical of moisture damged building (Samson 1999, Kujanpää *et al*. 2002). These findings led to extended renovation when all damaged materials were removed and replaced by new ones.

Spreading of microbial propagules was not effectively prevented during the renovation. 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 from where they could be detected in later sampling. Particularly the amount of *Chaetomium* spores was increased on surfaces after repair work. After repair, the building was cleaned by conventional methods with no special effort focused on removal of fine dust including microbes.

Surface sampling may be used to identify microbial diversity and the relative degree of biological contamination (Martyny *et al*. 1999). In microbiological analysis of material and surface samples, it has been found out that direct plating gives more information of microbial genera than dilution plating (Hoekstra *et al*. 1994, Reiman *et al*. 1999, Reiman *et al*. 2002). These were the reasons why we selected the direct plating of surface sampling as a tool to evaluate the sufficiency of cleaning.

After repair and the first cleaning made by conventional methods, most of the moisture indicating microbes detected before could be found on surfaces. The most probable explanation for this is that the cleaning procedure had been insufficient as shown also in other studies (Hung 1999).

Second time the building was cleaned using techniques adapted for thorough washing off mold dust. After this all-out cleaning, only four taxa were found in the surface samples. Of these four microbes remaining three were those of dry-spore fungi, and the fourth was *Chaetomium,* the predominant species on surfaces after repair in this building. Kokotti *et al*. (2002) found out that total elimination of exceptional microflora after the repair of moisture damaged building seems not to be successful, because spores migrate from external sources or sedimented spores resuspense from surfaces.

After 1_ months' use of the building, only few microbial colonies were found in the samples, although biodiversity of surfaces increased. This effect is evidently being caused by usual every-day activities (Lehtonen *et al*. 1993). People carry microbes with them from outdoors (e.g. *Cladosporium*), mold problem homes (e.g. *Acremonium*) or leisure activities (e.g. horse stable and gardens) to indoors, or they cause the resuspension of settled dust. The reappearance of some microbes may be explained by the fact that only part of the constructions which were recommended to be dried out, were actually dried, which allowed the survival of exceptional microflora in the constructions.

## CONCLUSIONS

Thorough repair of mold damages and subsequent effective cleaning are necessary actions in normalizing the microbiology of the building after repair of mold damages. Sufficient protecting of constructions during repair work is needed to prevent spreading of microbes and fine dust. According this study, all-out cleaning is required to get rid of mold dust arisen during repair of moisture and mold damages in the building.

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