Materials' microbiology in different elements of building

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ABSTRACT
The aim of the study was to find out if the location of material has effect on microbiological findings. Material samples (n = 735) were taken from the buildings with susceptible moisture damages. Viable fungal spores and bacteria were analysed from paperboard, insulation material and wood samples from inner and outer parts of construction. Microbial biodiversity was largest in inner parts of construction. In wall cavity, insulation material had largest microbial diversity. *Acremonium, Aspergillus versicolor, Stachybotrys, Trichoderma* and *Streptomyces* are examples of the microbes which seemed to be indicative of moisture damages if found in materials locating in the inner side of construction. According our results, the location of material affects the microbiology of the material. This information is useful in risk assessment. Possible transfer routes of microbes in different elements of building can be evaluated by stratified sampling over structure.

INDEX TERMS
Building; Structure; Material; Micro-organisms; Moisture damage; Risk assessment

INTRODUCTION
Users of buildings often complain about either perceived poor indoor air quality or increased prevalence of symptoms, the reasons of which may include moisture damages of the building or ventilation system (Halonen *et al.*, 2000). Because of numerous complaints concerning indoor air quality in several public buildings, technical inspection of the buildings was carried out. History of the buildings included, e.g. leaking roofs, lack of covered drains and flooding suggesting the possibility of damages caused by water. In addition to technical inspection of the building microbiological analyses of material samples are used as a tool when estimating the seriousness and extent of moisture damages (Martyny *et al.*, 1999). In interpretation of microbiological results, same criteria are used for all materials without taking into account the location of the material in the building. The aim of the study was to find out if the location of material has any effect on microbiological findings, and if this information is useful in risk assessment.

MATERIAL AND METHODS
Sampling sites in 58 buildings had visible signs of water damage. Material samples (n = 735) were taken mainly from different layers of wall constructions. Samples were paperboard (n = 208), insulation material (n = 310) and wood (n = 217) (Table 1). From all samples, 27% were taken from materials facing room space, 59% from materials in the inner side of wall construction, and 12% from materials in the outer

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side of wall construction. In subarctic climate, the inner side of wall construction is in warm conditions most of the year.

Viable fungal spores and bacteria were analysed from material samples by dilution method using three different media (Rose Bengal malt agar, dichloran glycerol agar (DG18) and tryptone yeast glucose agar (TYG)) (Samson and van Reenen-Hoekstra, 1996). The plates were incubated at +25 ± 3°C for 7 days. Microbes were identified using common mycological procedures.

Table 1 The location of material samples in different elements of building (*n* = number of samples)

Material	Facing room space (*n*)	In inner side of wall construction (*n*)	In outer side of wall construction (*n*)
Paperboard	46	154	8
Insulation material	40[a]	210[b]	60[b]
Wood	116	69	20

[a]Acoustic insulation.
[b]Thermal insulation.

RESULTS

Microbial Diversity in Different Elements of Building

Microbial biodiversity was largest in warm conditions, especially in wood samples facing room space or locating in inner side of wall construction. In wall cavity, the insulation material had largest microbial diversity (Table 2).

Table 2 The number of microbial taxa (*n*) in different elements of building

Material	facing room space (*n*)	In inner side of wall construction (*n*)	In outer side of wall construction (*n*)
Paperboard	22	22	6
Insulation material	21	38	25
Wood	32	30	16

Prevalence of Microbes in Different Elements of Building

Prevalence of *Penicillium* was quite high in all materials, being 33–65% depending on the material and its location. The prevalence of *Aspergillus versicolor* was lowest (13%) in insulation material and highest (39%) in wood samples facing room space. *Trichoderma* was most often (10%) found in wood samples in inner side of wall construction, in other samples its prevalence was <5%. *Stachybotrys* and *Fusarium* were not found in the outer side of wall construction. The prevalence of *Stachybotrys* was 18% in paperboard samples taken from the inner side of wall construction.

Concentrations of Microbes in Different Elements of Building

Figures 1–6 display average concentrations of selected microbes in different materials.

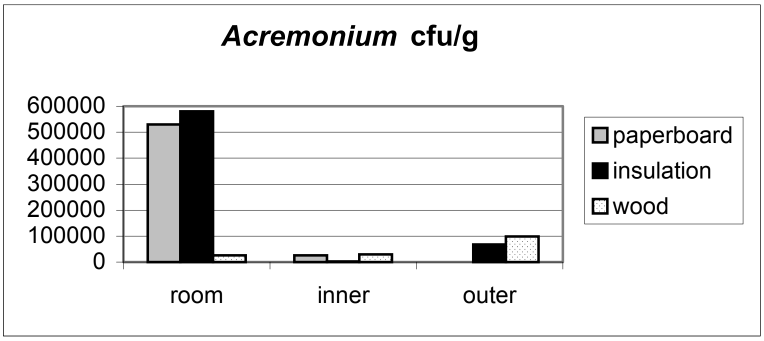

Figure 1 The concentrations of *Acremonium* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

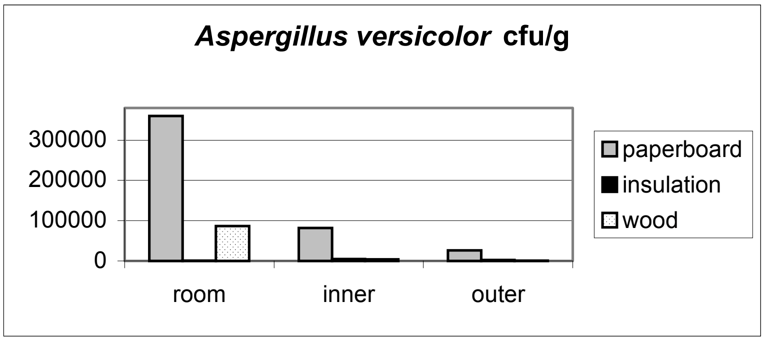

Figure 2 The concentrations of *Aspergillus versicolor* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

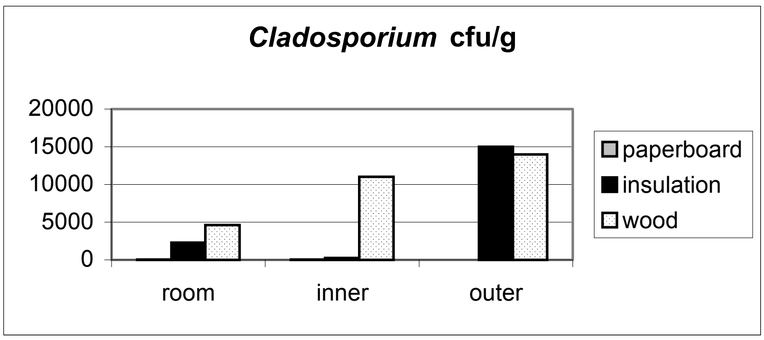

Figure 3 The concentrations of *Cladosporium* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

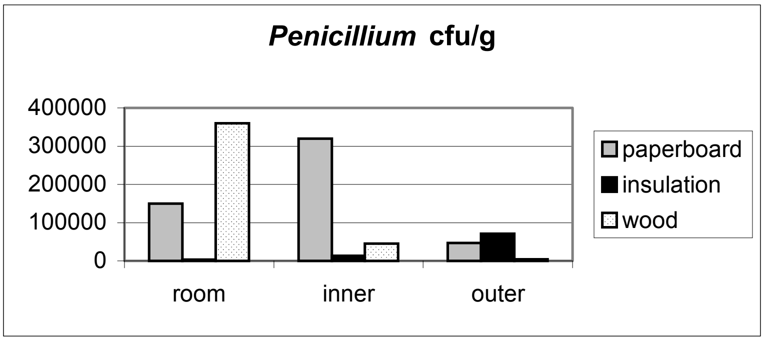

Figure 4 The concentrations of *Penicillium* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

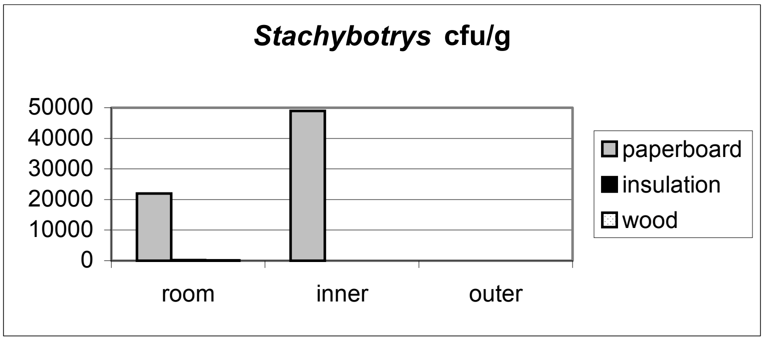

Figure 5 The concentrations of *Stachybotrys* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

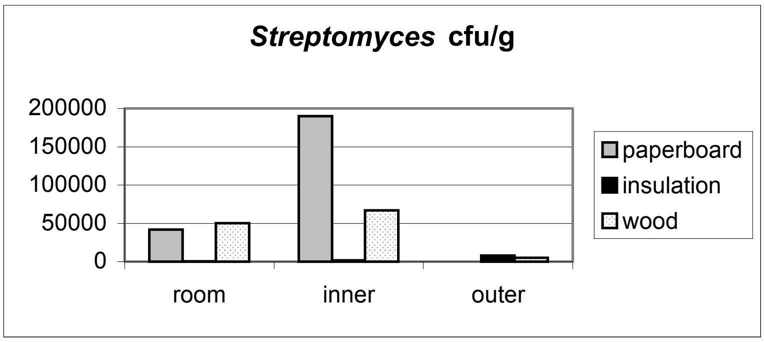

Figure 6 The concentrations of *Streptomyces* in material samples in different elements of building (room, facing room space; inner, inner side of wall construction; outer, outer side of wall construction).

Microbes in Different Materials

Highest concentrations of *Aspergillus versicolor* (1.4×10^6 cfu/g), *Stachybotrys* (3.3×10^5 cfu/g), *Chaetomium* (1.9×10^6 cfu/g) and *Streptomyces* (1.5×10^6 cfu/g) were found in paperboard samples and *Trichoderma* (3.4×10^5 cfu/g) in wood samples, respectively.

DISCUSSION

Microbial diversity was largest in warm conditions, i.e. facing room space or locating in inner side of wall construction, especially in wood samples. In wall construction, insulation material had largest biodiversity independent of whether the outer or inner side of the insulation was analysed. Insulation material has been reported to have versatile microbial flora also in other studies (Kujanpää *et al.*, 1999, Hyvärinen *et al.*, 2002).

As pointed out by Martyny *et al.* (1999), it is important to make difference between microbes that colonize the material or have accumulated in the material and originate from other sources. In our study, *Cladosporium* was a common fungus in samples taken from wall cavity, and its concentrations diminished towards inner constructions suggesting its outdoor source (Laitinen *et al.*, 2000). Filter effect of insulation might explain high prevalence and concentrations of *Cladosporium* as suggested also by Reiman *et al.* (2000) and Hyvärinen *et al.* (2002). Although spores were found in high concentrations from materials of the outer side of wall construction, they seem to have a small chance to enter room space through wall construction, thus creating only minor risk to building users.

On the basis of high concentrations, *Acremonium, Aspergillus versicolor, Stachybotrys, Trichoderma* and *Streptomyces* seem to have colonized the materials. They are examples of the microbes which are indicative of microbial damages if found in materials locating in warm elements of building. They all possess the potential for production of toxic metabolites (Samson, 1999, Salkinoja-Salonen *et al.*, 1999, Tuomi *et al.*, 2000). The health risk constituted by these microbes is high (Burge *et al.*, 1999), because (1) they have great probability to transport into indoor air due to their location enabling the dissemination from the source, (2) spores or hyphal fragments may come airborne with air currents through constructions or mechanical disturbance directly from the surfaces facing room space creating probable exposure and (3) they may cause toxic health consequences due to potential exposure to mycotoxins or mVOCs.

CONCLUSIONS AND IMPLICATIONS

Material samples are useful in locating the source for potential microbial exposure.

Possible transfer routes of microbes in different elements of building can be evaluated by stratified sampling over structure.

According our results, the location of material affects the microbiology of the material.

The location of microbe-damaged material is a useful piece of information in risk assessment if combined with other information of microbe-related risk factors.

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