Building materials vs. fungal colonization – model experiments

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Abstract

The antifugal potential of indoor building materials of 7 different types – without as well as with a paint or oily coating – was studied according to the ISO 846: 1997 E. Spore suspensions of micromycetes *Acremonium* sp., *Aspergillus ustus, A. versicolor, Cladosporium sphaerospermum, Penicillium* sp. and *Scedosporium apiospermum* were inoculated onto the materials' surface (clean and dusty – to simulate the real state in the indoor environment). Systems were kept under defined water activities (a_w) 0.94, 0.83 and 0.75 and incubated at 22–25°C for 3 months. Microbial growth was evaluated visually after the 1st, 2nd and 3rd months of the experiment. At the end of the period, the vitality of fungal propagules on the material surfaces was estimated by the printing method onto Sabouraud agar medium. All building materials with any lime composition or oily coating showed a certain resistance to the fungal colonization, even under very moist conditions ($a_w = 0.94$). Thus, their broader employment in the indoor environment could be emphasized. Representatives of the common airborne mycoflora – aspergilli, penicillia, and *C. sphaerospermum* – were able to develop visible growth on all materials tested with and without the house dust as well, although the colonization was of different degrees depending on the humidity. The fungi of *Acremonium* sp. and *S. apiospermum* favoured – as had been expected – the highest $a_w = 0.94$ the most. No building material showed fungicidal properties – micromycetes were capable of germinating when printed from the material surface onto the agar. The dust reduced the materials' antifungal properties only very moderately. *A. versicolor* – a producer of carcinogenic mycotoxin sterigmatocystin – could colonize materials under any experimental conditions. Wooden facings seemed to be the most resistant to the moulds.

Keywords: building materials, indoor environment, moulds, water activity, temperature, antifungal properties.

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1 Introduction

Monitoring of exposure to indoor fungi is rather complicated due to lack of standard and exact practical methods to evaluate how indoor microclimate (temperature, relative humidity, dust, ventilation, constructing materials and furnishings), outdoor ambient, and microscopic fungi affect each other.

It was found that alternaria-propagules were predominant mainly in dwellings not heated sufficiently, aspergilli colonized houses and flats with wallpaper especially, while concrete surfaces favoured cladosporia [1]. The ability of *Penicillium* sp. and *Aspergillus* sp., the so-called first colonizers, to grow on/in common house-dust under a relative humidity of 76–80% can probably explain their dominant prevalence even in healthy buildings. The secondary (*Cladosporium* sp., *Alternaria* sp., *Chaetomium* sp., 85% relative humidity needed) and tertiary colonizers (*Fusarium* sp., *Acremonium* sp., yeasts, optimal relative humidity above 90%) are able to biodeteriorate any constructing material (plaster board, concrete, lime-cement and cement plasters, brick and ceramic tiles, paintings, wood, paper etc.) under optimal thermal and moist conditions. This was proved by several studies of mouldy dwellings in Slovakia [2–4].

The *Stachybotrys chartarum* isolates from moist schools and dwellings in Denmark produced trichothecenous mycotoxin trichodermol when cultivated onto cardboard [5] and vinyl ceiling [3]. Mutagenic and foetotoxic mycotoxins alternariol and its monomethylether adversely affecting mice were detected in cellulose tiles overgrown with *Alternaria alternata*. This isolate was also able to grow on cardboard [6]. The metabolite synthesis of fungi depends on the quality of constructing materials (e.g. [7, 8]). In our previous experiments on tracheal organ cultures of 1-d-old chicks, varying ciliostatic activity was found in chloroform extracts of biomass from building materials (mineral wool, plasterboard, cardboard) inoculated with pure isolates of some moulds of indoor origin (*Penicillium chrysogenum, P. palitans, Trichoderma viride, Stachybotrys* sp. and *A. versicolor*). Generally, extracts from growth on materials composed of finely divided cellulose were more active than those from growth on mineral wool [9].

2 Materials and methods

A testing method according to the modified ISO 846 was used [10]. It is possible to distinguish between the fungal resistance of a material on its own (growth test) and fungistatic/fungicidic properties of that material in the presence of the complex growth medium (fungicidic test) under defined conditions (23–25°C – growth of mesofili, relative humidity 95% min., 4 weeks, also with dusty materials – real conditions' simulation).

Samples of the following building materials – without as well as with a paint or oily coating – were evaluated for their antifungal properties: fine, grain and traditional lime plaster, traditional gypsum mortar, joint cement, ceramic tiles, wooden facings.

Spore suspensions of micromycetes *Acremonium* sp., *Scedosporium apiospermum* (belonging to tertiary indoor fungal colonizers as indicators of long-lasting dampness and depending on essential nutrients in the environment), *Aspergillus ustus, A. versicolor* – a toxic fungus, *Penicillium* sp. (so-called primary indoor colonizers, components of a common airborne mycoflora of any non-sterile environment) and *Cladosporium sphaerospermum* as a representative of secondary indoor colonizers commonly present in the outdoor fungi were inoculated onto materials' surface (clean or dusty). Systems were kept under defined water activities (a_w; processed by NaCl as given in the STN 56 0030 [11]) 0.94, 0.83 and 0.75 and incubated at room temperature (22–25°C) for 3 months. Microbial growth was evaluated visually after the 1st, 2nd and 3rd months of the experiment. At the end of the period, the vitality of fungal propagules on the material surfaces was estimated by the printing method onto Sabouraud agar medium.

3 Results and discussion

3.1 Building materials without house dust layer

Wood and lime plasters were shown to be the most resistant to fungal growth under given experimental conditions, while tiles and plaster mortars enabled all microfungi to growth.

No painting or coating changed this resistance, but:

- An oily coating appeared to be more antifungal than common watery painting,
- *Acremonium* sp. was able to growth on all materials tested only when cultivated at $a_w = 0.94$,
- *Aspergillus versicolor* and *Penicillium* sp. overgrew materials under all moisture conditions, except for wood and a fine lime plaster, when they grew only at $a_w = 0.94$ after 3 months,
- none of the materials tested showed any fungicidic potential as micromycetes remained cultivable after 3 months of the experiment under all moistures used, fig. 1–3.

3.2 Dusty building materials

Wood (naked as well as coated) was again the most fungal-resistant. Ceramic tiles and silicone cement with oily coating had a lower resistance and, finally, the cement with painting was proven, too. *Acremonium* sp. did not even colonize any of the wooden samples tested, and on the others grew only occasionally. *A. versicolor* colonized all systems of dusty building materials under the given moisture conditions. Thus, the house dust affected antifungal properties of the materials only very moderately, fig. 4–6.

Notes to figures
0 – no growth of moulds, 1 – microscopically visible colonization, 2 – visible growth, 25% surface, 3 - 50% surface, 4 – more than 50% surface, 5 – overrun.

A – fine lime plaster Terra R-605, B – traditional lime plaster, C – ceramic tiles, D – grain lime plaster Terra 141 P, E – joint cement (silicone), F – traditional gypsum mortar, G – wood

■ *C. sphaerospermum,* ■ *Acremonium sp.,* ■ *A. versicolor,* ■ *A. ustus,* ■ *Penicillium sp.,* ■ *Scedosporium apiospermum*

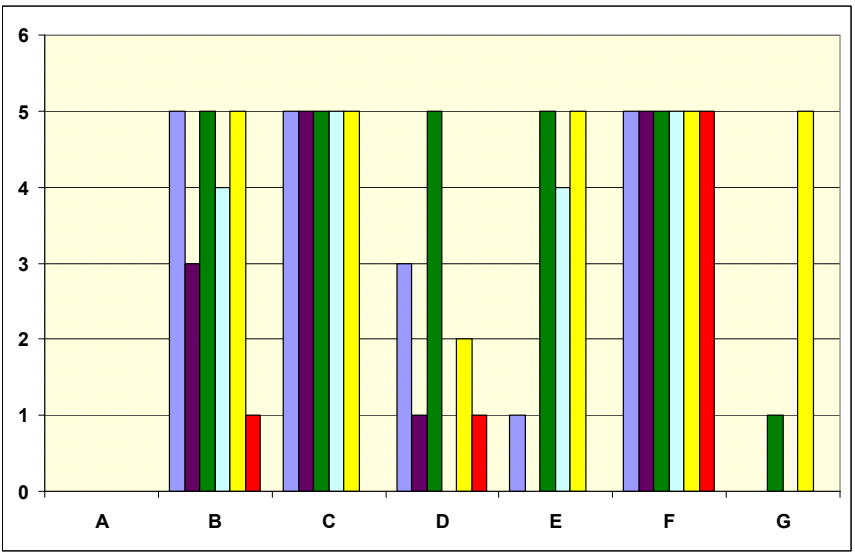

Figure 1: Fungal colonization of building materials under their water activity 0.94.

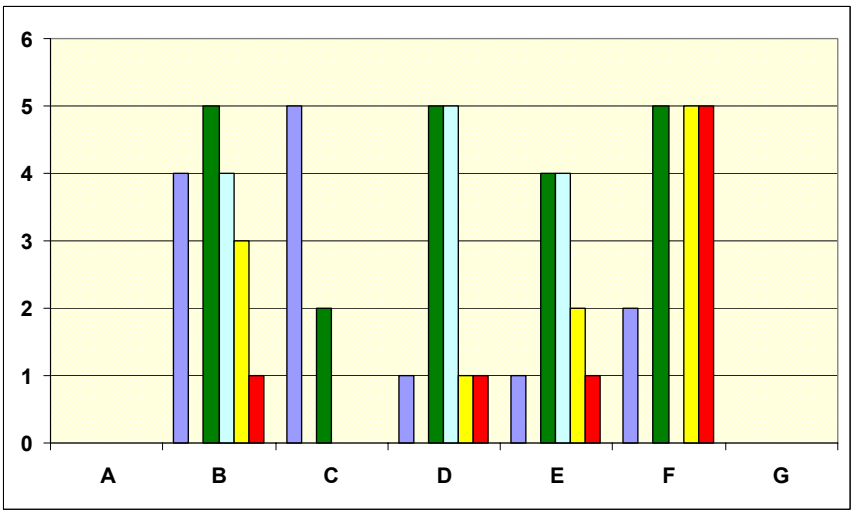

Figure 2: Fungal colonization of building materials under their water activity 0.83.

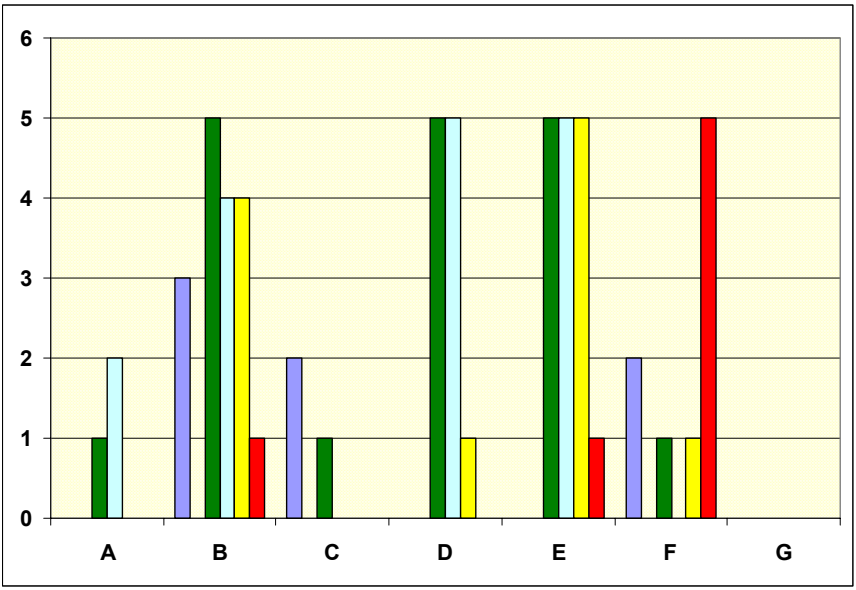

Figure 3: Fungal colonization of building materials under their water activity 0.75.

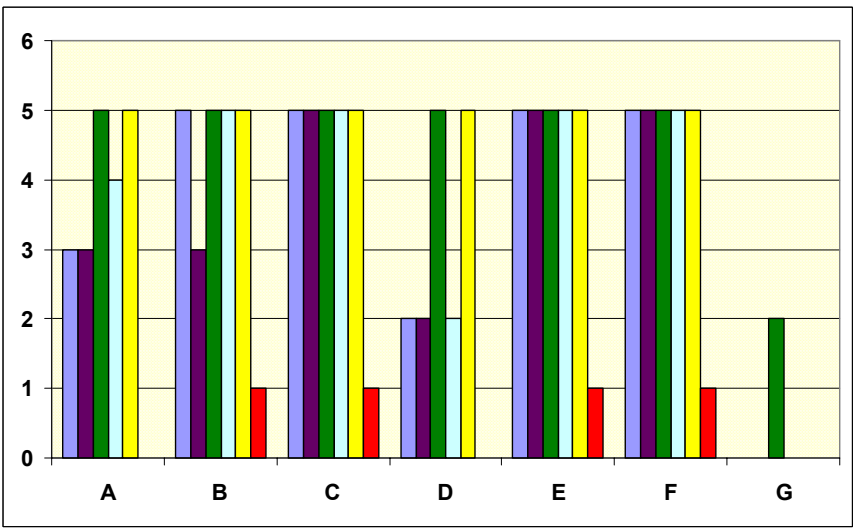

Figure 4: Fungal colonization of dusty building materials with water activity 0.94.

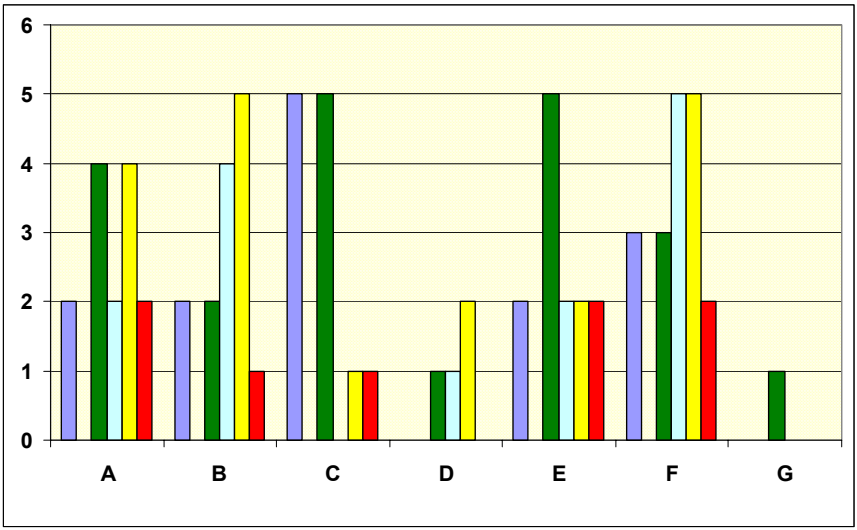

Figure 5: Fungal colonization of dusty building materials with water activity 0.83.

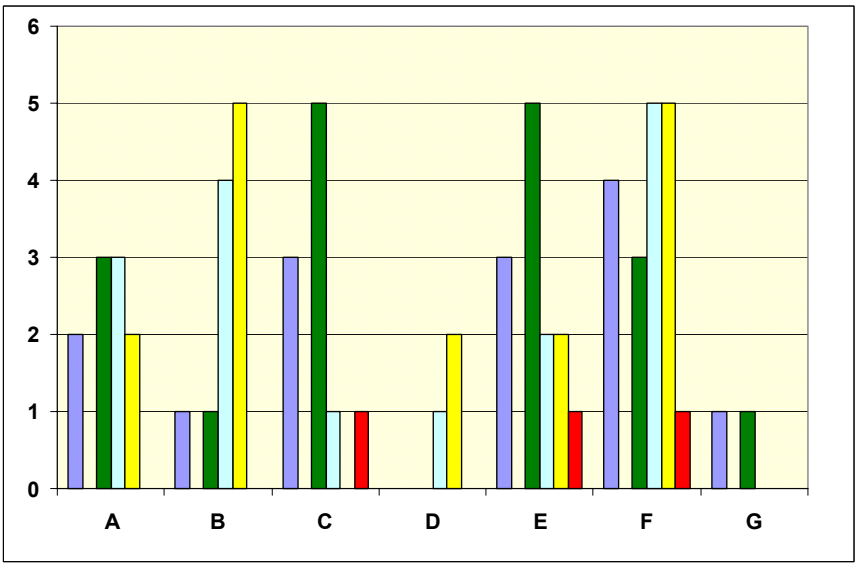

Figure 6: Fungal colonization of dusty building materials with water activity 0.75.

Actually, the results proved that – from the fungal colonization point of view – the physical characteristics (diffusion properties and moisture content) of the building materials used in the construction are the most potent factors affecting the appearance and development of the moulds. Finally, the presence of the house dust on the materials' surfaces did not promote their fungal colonization extremely. Less porous or materials that were easily dried were, generally, more resistant to the fungal colonization. The same could also be said about their coating types. Anyway, fungal growths depended on the particular moulds as well.

4 Conclusion

In the model of the 3-month experiments, all building materials with lime components or oily coating showed a certain antifungal resistance, including under very damp conditions ($a_w = 0.94$).

Representatives of common airborne fungi – the primary colonizers of the surfaces, aspergilli and penicillia, and the secondary one *Cladosporium sphaerospermum* visibly grew on samples tested – clean or dusty (simulation of real indoor "dirty" surfaces), although in particular extension due to given moisture conditions. The tertiary colonizers *Acremonium* sp. and *Scedosporium apiospermum* fulfilled the expectation – an especially, high $a_w = 0.94$ favoured their development on the materials.

No material seemed to be fungicidal – mould propagules kept their vitality expressed as the ability to germinate on a complete nutrient medium (Sabouraud agar) after 3 months of the experiment.

Wood, both naked and with coating, may be considered as the most fungal resistant building material – a possible effect of natural terpenes – but no celulolytic microorganisms were employed.

Antifungal properties of indoor materials' surfaces could be improved by coatings, even in very damp spaces ($a_w = 0.94$, bathrooms, kitchens). The traditional mortar materials were shown not to be proper mycologically even in the environment with the lowest $a_w = 0.75$, which is common in the rooms with a wrong household regime (e.g. too little or incorrectly ventilated and heated sleeping rooms).

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