Mould growth on painted wood

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ABSTRACT

Wood is an organic and heterogenous material and susceptible to mould growth and bluestain fungi. The whole production chain of wooden products affect the durability: wood quality, processes, structures and end use conditions. In the end use condition, the humidity, temperature and the exposure time are often the main factors. Level and duration of moisture stress connected with temperature are the most critical factors for the mould growth and bluestain on wood. Biocides are used to protect the wood surface and paint film against microbial growth, especially bacteria, blue-stain and mould fungi. Differences in the efficacy of the fungicides to protect the paint film are found. The quality of wood material, type of paint film, application of fungicides, weathering and moisture exposure affects on the performance of painted wood. In the tests performed at VTT, the most effective combinations were free from mould growth after 26 weeks at RH 100 %. The surfaces of acrylates having dipping treatment, primer and topcoat with fungicides performed relatively well after agressive test. The natural weathering and wooden material also affected the resistance of paint films against blue-stain and mould fungi. After 6 month's natural weathering, growth of blue-stain fungi and mould fungi was found on the untreated wood and on the paints films without fungicides. After subsequent incubation at RH 100 %, growth of mould and blue-stain fungi was very agressive. The surfaces from kiln dried pine and spruce sapwood were more susceptible to fungal attack than the resawn surfaces from spruce sapwood but the application of fungicides in the different treatment layers affected the durability of outer layer against mould and blue-stain fungi. Several studies on the factors known to affect the development of mould fungi on wood has been carried out at VTT. It was shown that mould growth is significantly more rapid and vigorous on the original kiln dried wood surface than on the resawn surface. Spruce sapwood proved to be slightly less suscepectible to mould than pine sapwood.

KEYWORDS

Fungicides, mould fungi, wood, water-based paint, durability

INTRODUCTION

Several factors affect the durability of wooden products against mould and decay (Figure 1). Exterior wooden facades, windows and other constructions are exposed to weather stresses: rain, high humidity and sun light**.** Several factors affect performance and durability properties of painted wood constructions. One important factor is discolouring fungi (mould and bluestain fungi). The critical limit for mould growth on wood is around RH 75 - 80 % (constant ambient air humidity), but mostly higher relative humidity, around 90 % (wood moisture content around 20 %) is required for growth. The actual limit depends on temperature, exposure time, material and fungal species (Wang 1992, Viitanen 1996, Ritschkoff et al 2000). The durability of wood material is also dependent on

the quality of wood, e.g. the amount and quality of primary metabolites, storage compounds and the extractives of wood. The amount of primary metabolites such as sugars, lipids, peptides and starch varies in pine and spruce sapwood (Theander et al. 1993). The extractives are waxes, fats, free fatty acids and alcohols, steroids, higher carbon compounds and resins.

Fungicides are or should be used in paints against microbial growth. Several factors affect the ability of fungicides to protect the paint films: eg. environmental factors (humidity, temperature, exposure time, organims envolved), structures, wood quality, preservative treatments, type and composition of paint, the fungicides used and their reactions with components of paint (Bjurman 1994, Bjurman and Herder 1992, Viitanen 1996, Viitanen and Ahola 1999).

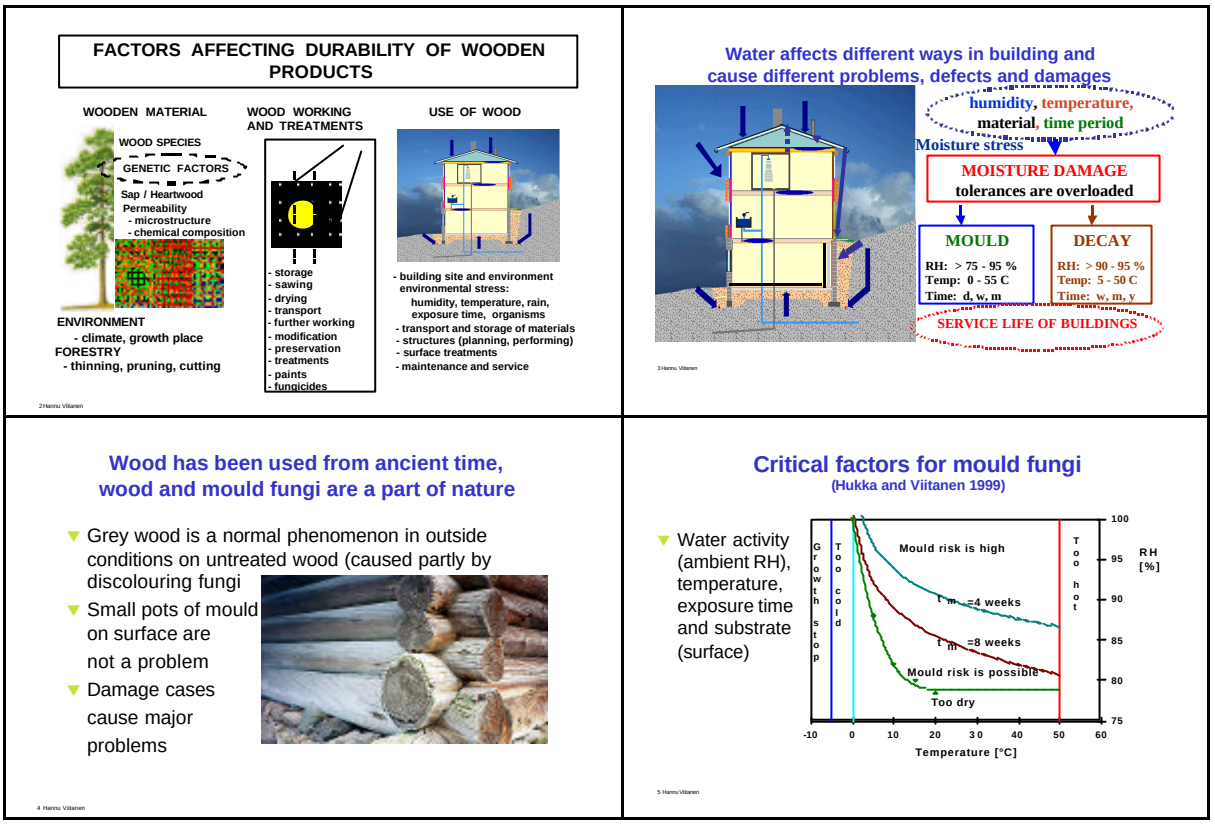

Figure 1. Factors affecting the durability of wood against mould and decay. Critical factors for the growth of mould fungi and the role of mould and bluestain fungi to produce gray wood.

Factors affecting mould growth on wood

The effect of fungicides in the paint film

Kiln dried pine panels (25 x 120 mm) containg mainly sapwood were selected in a sawmill in south Finland. The wooden miniboards (10 x 45 x 500 mm) were sawn from the pine and spruce panels at VTT. The samples were sawn from the inner part of panels (5 mm from the original dried sapwood surface) of pine sapwood (part one). In the second part, also kiln dried original surfaces were used (Figure 2). The samples were stored at RH 65 % and 20 °C prior to treatments.

Acrylate and alkyd model paint systems 1, 2 , 3 and 4 produced in the EU project CT94-2463 in the AIR programme of DG XII (Ahola et al 1998) were used in the part one. In the part two, only model paints 1 and 2 were used. The pigment volume concentration (PVC) was 25 % in the acrylate primer and 15 % in the acrylate topcoat. The alkyd primer and topcoat were equal. The fungicides and their concentrations are presented in the table 1. Concentrations of fungicides in the primers and paints have been evaluated on the basis of recent studies and on the notes from the producers of the fungicides and paints. The fungicides have been mixed with the model paints by Tikkurila Oy, Finland.

Table 1. The concentrations (% w/w) of fungicides and their combinations in the primers and topcoats (as active agents).

Fungicide	**Primer (% w/w)**	**Topcoat (% w/w)**
0) no fungicide	0.00	0.00
1) propiconazole	0.75	0.40
2) isothiazolon	0.45	0.23
3) IPBC	0.30	0.15
4) propiconazole + IPBC	0.50 + 0.2	0.25 + 0.12
5) propiconazole + isothiazolon	0.50 + 0.2	0.25 + 0.14

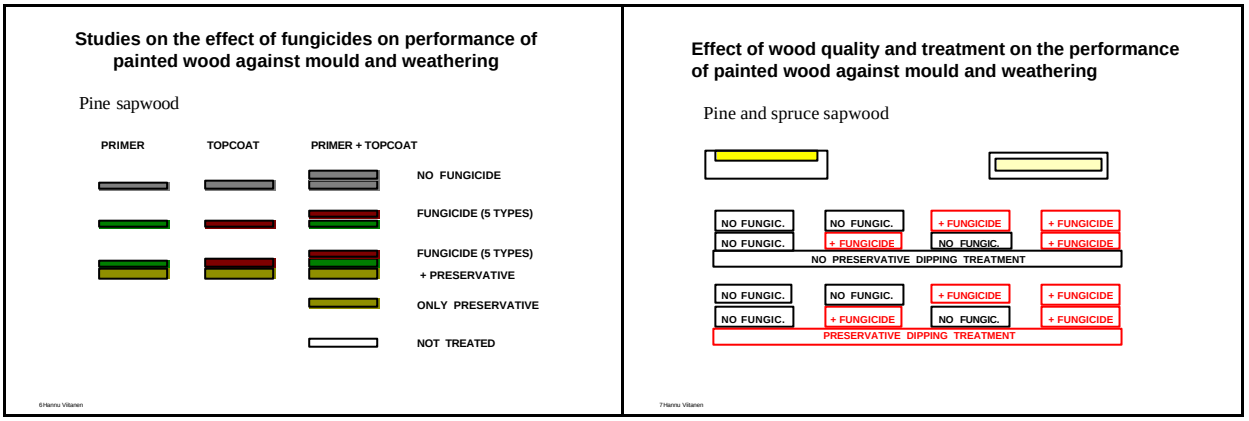

Figure 2. Different treatment systems for a) to study the effect of fingicides on pine sapwood and b) to stydy the effect of wood quality and treament level on mould growth on pine and spruce sapwood.

To study the effect of wood quality (second part), the resistance of acrylate paint systems on different types of pine and spruce sapwood to mould fungi was studied (Figure 2 b). Dipping into the preservative prior to painting, a primer with and without a fungicide (propiconazole + IPBC 0.50 + 0.2 %) and a topcoat with and without a fungicide (propiconazole + IPBC 0.25 + 0.12 %) were combinations of the treatments studied.

The growth of mould fungi was evaluated using the mould index ant the rate of mould growth was classified between 0 and 4:

0 no growth
1 trace of growth detected visually
2 slight growth or 5 - 20 per cent coverage of total test area

3 moderate growth or 20 - 50 per cent coverage
4 plenty of growth or above 50 per cent coverage.

The incubation of the samples was made principally according to the Nordtest NT build 338. The humidity level of chambers (RH 100 %) was adjusted by heat controlled system below the chambers (Figure 3).

The samples were placed horizontally in the chambers and sprayed with mixed spore suspensions of different mould fungal colonies (e.g. *Aspergillus versicolor*, *Aureobasidium pullulans*, *Cladosporium sphaerospermum*, *Penicillium* sp. *Trichoderma* sp.). The assessment has been carried out several times during the 6 months' incubation in the chambers. After exposure, some samples were assessed by means of light microscope to limited extent and moisture content of the painted and unpainted samples were measured by means of the weighing-drying method.

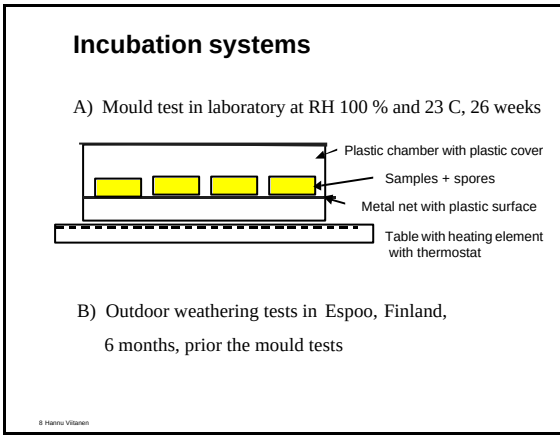

Figure 3. The incubation system for mould test in laboratory. Prior the mould test, also 6 monts's weathering in outdoor conditions was used.

RESULTS AND DISCUSSION

The efficacy of fungicides in the acrylate and alkyd paints

After the incubation at RH 100 % and 20 °C, the growth of mould fungi on the untreated pine sapwood samples was vigorous. The concentration of the fungicides in the primers was higher and thus the protective effect of the primers with fungicide was better than that of the topcoats concerning the unweathered material. The results indicate that there was no significant difference in mould resistance between the tested unweathered acrylate and alkyd coatings, but the used fungicides showed different resistance against mould growth (Figure 4). The acrylate topcoat (PVC 25 %) without any fungicide appeared to be more resistant against mould growth than the acrylate primer (PVC 15 %) without any fungicide. IPBC showed a sufficient efficacy against mould growth even at the low concentration used, but at the later stage, the resistance of all fungicides decreased. The mixtures of the fungicides (propiconazole + IPBC and propiconazole + isothiazolon) even at the low concentration used were much more effective against mould growth than propiconazole even at higher concentration. The dipping treatment prior to priming and painting increased the resistance of the surface against mould growth.

Within weathered material, more fungal growth was found during the subsequent incubation at RH 100 % (Figure 5). Especially the samples painted only with primer or topcoat were more attacked

by blue-stain and mould fungi than the samples treated with primer and topcoat. Also decay was found on the untreated material and within series were no fungicides were used.

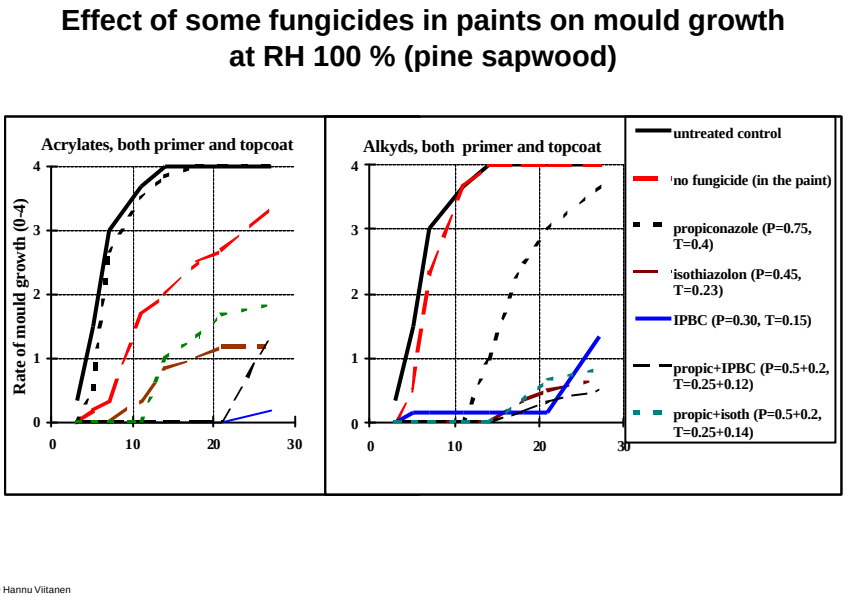

Figure 4. Results on the effect of fungicides on mould growth on painted pine sapwood after 26 weeks' exposure at RH 100 %

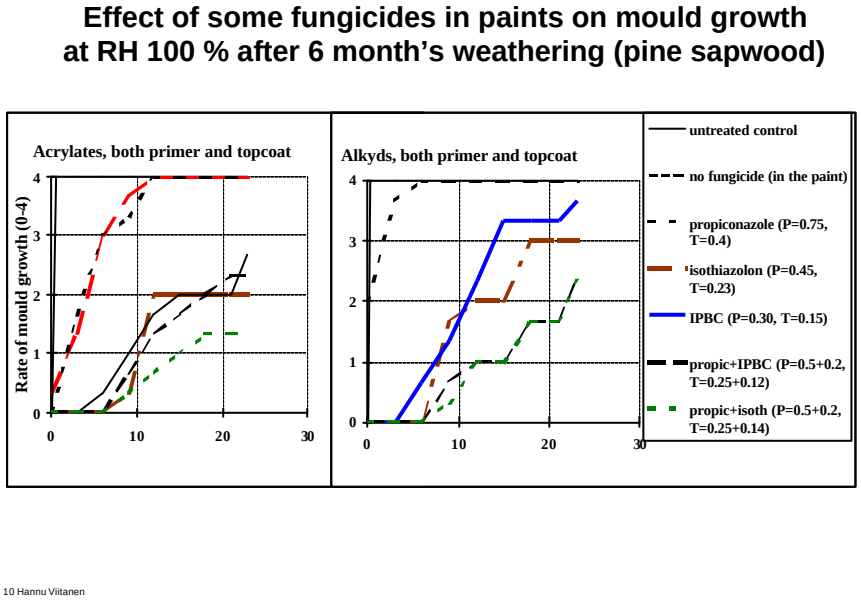

Figure 5. Results on the effect of fungicides on mould growth on painted pine sapwood after 6 months' weathering and 24 weeks' exposure at RH 100 %..

The results indicate that even 6 months' weathering has a significant effect on mould and blue-stain resistance of the acrylates and alkyds incubated in high humidity. Especially the thinner films of acrylate primer or topcoat without fungicides tended to cracked and blue-stain fungi were found in the cracks. Growth type of blue-stain fungi was similar on the untreated wood: growth was mainly

found in the cracks. On the alkyd film, growth type of mould and blue-stain fungi was different: fungi was mainly found on the outer surface of the paint.

In the mould test, the growth of fungi was more vigorous on the weathered samples than on the unweathered ones. When no fungicide was used, the mould growth was more vigorous on alkyds than on acrylates. The effect of weathering was observed especially on the samples with only a primer or a topcoat. This indicates that the film thickness affects the performance of paint film against weathering and fungi. The concentration level of fungicides, however, was low being close to the limits of efficacy.After weathering, the growth rate of mould and blue stain fungi was high on the exposed surfaces, but lower on opposite, unweathered surface (especially on samples having thicker coating).

Bjurman et al. (1991) found different mould resistance of various paints and fungicides depending also on the mould fungal species, and the results of Bjurman and Herder (1992) indicated, that interactions between fungicides and water-borne coating are strongly dependent on the types of both. In the present study, the samples dipped in the preservative as such supported more mould growth than the untreated control samples. However, the dipping treatment prior to priming and painting increased the resistance of the surface to mould growth. The preservative in the dipping treatment contained 0.5 % troysan polyphases (100 % IPBC), which has been showed to be effective against mould growth in traditional solvent-borne preservatives (Grant et al 1986). In the present study, however, it was mixed with a water-borne alkyd binder.

The effect of wood substrate

Also wooden substrate and the location of fungicide in the treatment system affected mould growth on the paint films (Figure 6 a and b)). Within every treatment system, mould growth was most vigorous in the samples from yellow original surfaces of pine sapwood (which had been exposed to the atmosphere during kiln-drying). Also the yellow original spruce surface as such and exposed to mould growth before the treatments proved to be more susceptible to mould growth than the resawn samples taken at 10 mm below the original surface. Mould growth was vigorous also on the resawn pine sapwood samples .

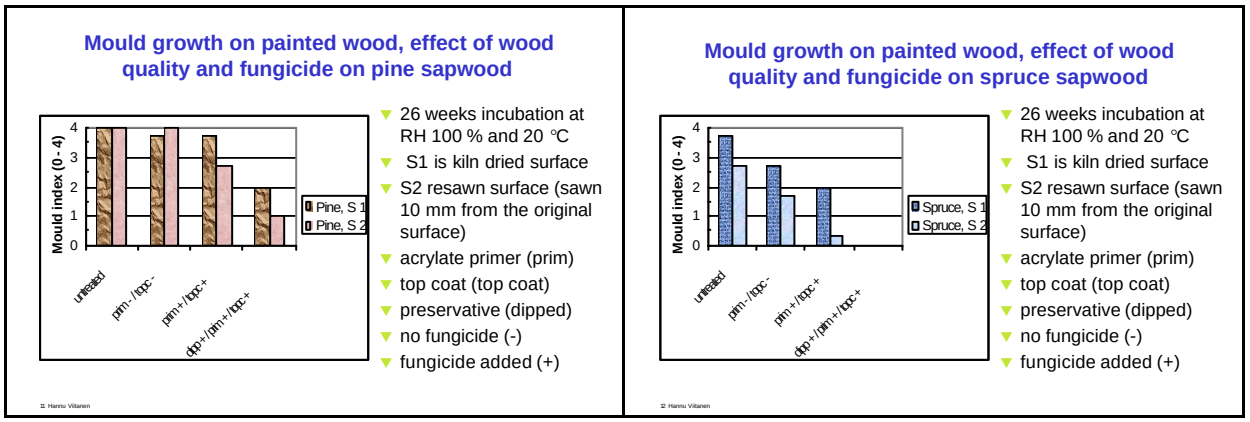

Figure 6. The mould growth on different painted pine (a) and spruce (b) sapwood after different treament systems.

After weathering, the exposed surfaces of all untreated and unpainted wood samples were attacked heavily by blue-stain fungi. In pine sapwood samples, also lower unexposed surfaces were attacked partly. However, no growth of blue-stain fungi was found on the lower surface of the samples which were treated by the dipping treatment. After weathering, no growth of blue-stain and mould fungi on the painted surface was detected, even though no fungicides were used. In this part of the mould study, the samples were painted both with a primer and topcoat and no cracking was found after outdoor weathering.

The most effective treatments which consisted of a dipping treatment, primer and topcoat with a mixture of the fungicides on resawn spruce surfaces were free from mould growth after 6 month's weathering and after subsequent 23 weeks mould test at RH 100 % . On the untreated samples and on the painted samples without fungicides, very active growth of mould and blue-stain fungi and also decay was found. Calculated mass loss values of samples from pine and spruce sapwood with the high nutrient content were higher than those of spruce sapwood with the low nutrient content. Moisture content of the samples having decay was higher than that of samples without decay.

The topcoats with the fungicide were most effective against mould growth in every wood type and no decay was found. The treatments with the fungicide only in the primer but not in the topcoat had better efficacy against mould than those without fungicide in the primer and topcoat. The dipping treatment as such did not prevent the mould growth and decay, but the dipping treatment prior to priming and painting increased mould resistance.

Obviously the nutrients from the kiln-dried yellow surfaces of pine and spruce sapwood added the susceptible of painted surface to mould growth more than on the spruce surface sawn from 10 mm below the original kiln dried surface. After weathering, however, mould growth on the original pine and spruce sapwood was not so vigorous as expected . This phenomena may be due to a leaching effect of precipitation: low molecular sugar and nitrogen compounds present in the wood may migrate to the surface during weathering and may be leached from the wood surface and from coatings. However, also leaching of fungicides from paint film may be resulted.

It is known, that the nutrients (low molecular sugar and nitrogen compounds) present in the wood are able to migrate to the surface of lumber during kiln-drying (Viitanen and Bjurman 1995, Terziev et al. 1994). The nutrient rich pine and spruce sapwood painted with the different acrylate paint systems showed heavy mould growth in relation to the surfaces sawn 10 mm from the original kiln dried surfaces (Viitanen and Ahola 1999, Bjurman et. al. 1994) found that activity of fungi depended on paint types and fungicides and their tendency to leach. It is reported, that the whole intermediate zone between wood and outer surface (preservative, primer and top coat) is very important for the resistance painted wood to micro-organisms (Schoeman and Dickinson 1996). This study confirms the observation: the triple treatment system was the most effective against mould and blue-stain growth.

CONCLUSIONS

Several factors affect mould resistance of painted wood:

- wood material, permeability and nutrient content on the wood surface

- paint type, fungicides and their concentration in the paint
- wood quality connected with preservation and application of fungicides in the pretreatments, primers and paints
- use of products, climatic exposure conditions and exposure time, structures and service
- colonies of microbes and fungi in materials and in ambient environment..

In buildings, mould fungi can cause severe problems in structures and materials. In future, more attention should be focused on the protection of surface subjected to high humidity and environmental stress (facades, attics, windows, surfaces of wet rooms). Effect of different factors should be included in this aspect and more knowledge on the durability of fungicides, paints and wooden products is needed.

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