Fraunhofer Institut Bauphysik

Mold Formation in Cathedral Ceilings: Hygrothermal Analysis and Solutions

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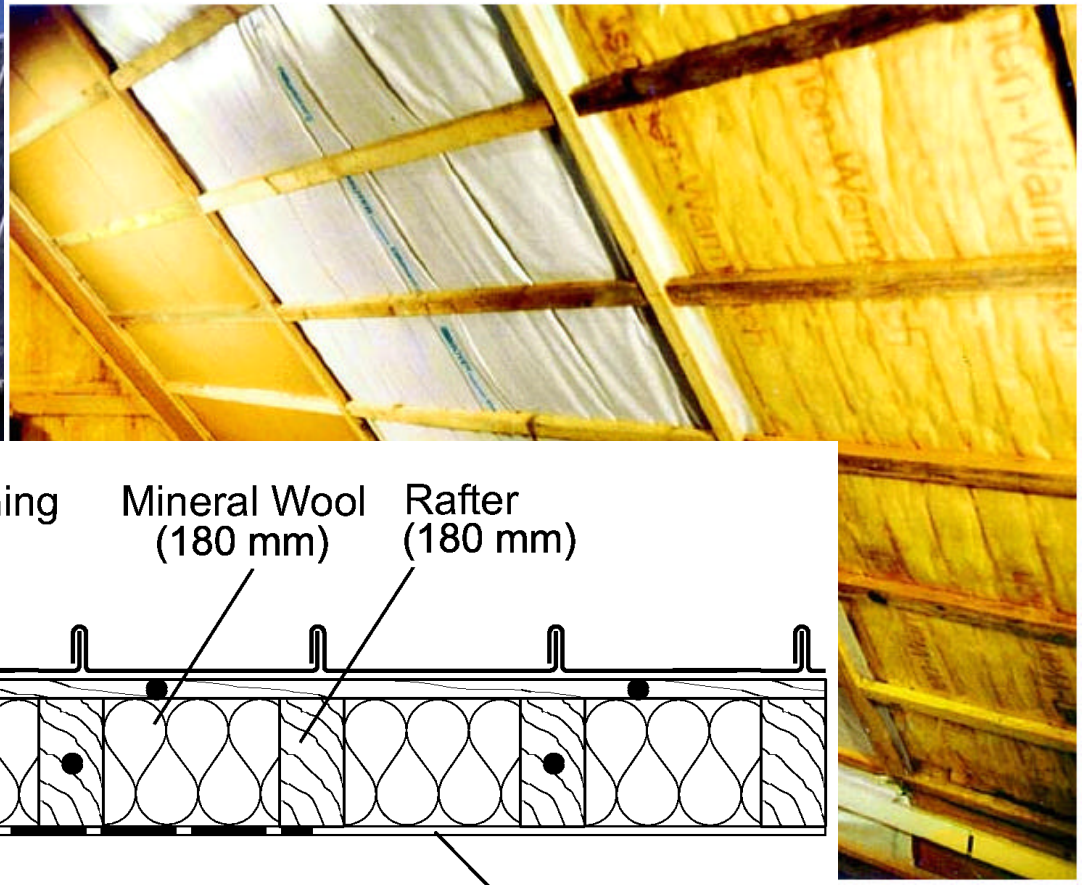
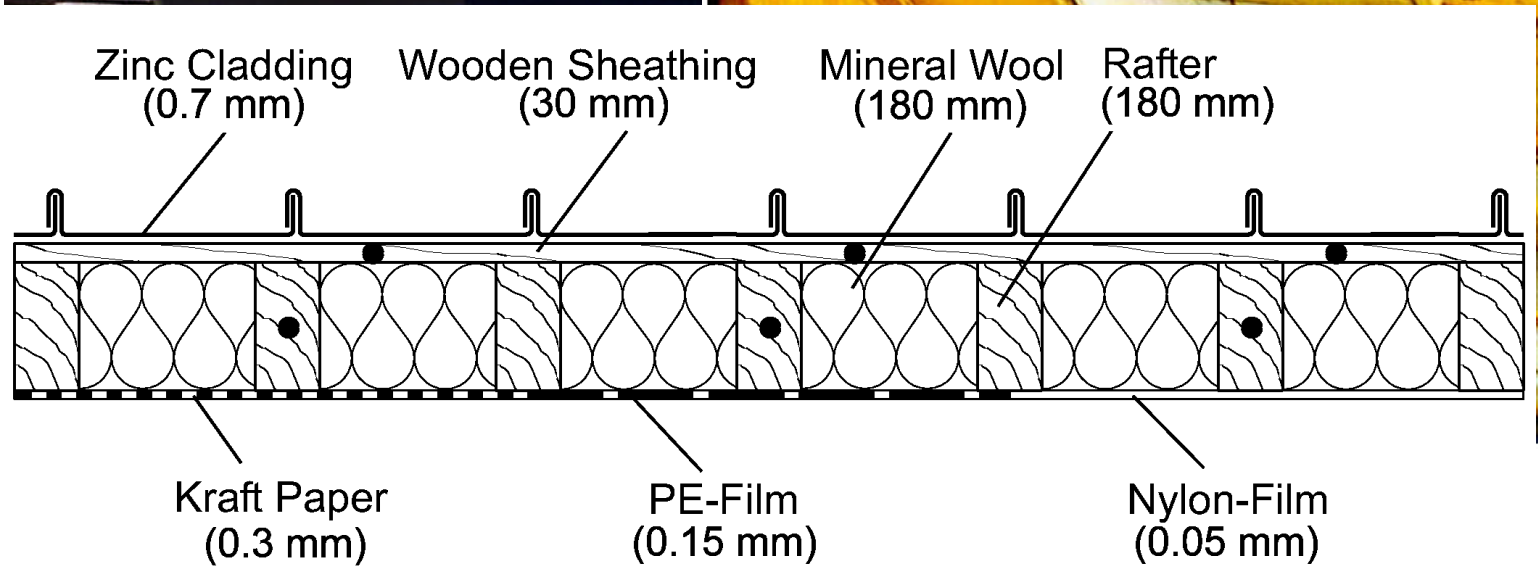
- Problem: mold detected during a field test
- Analysis of the hygrothermal conditions
- Biohygrothermal model for mold prediction
- Conclusions

Field Test Site in Holzkirchen

Cathedral Ceiling with Metal Sheet Covering



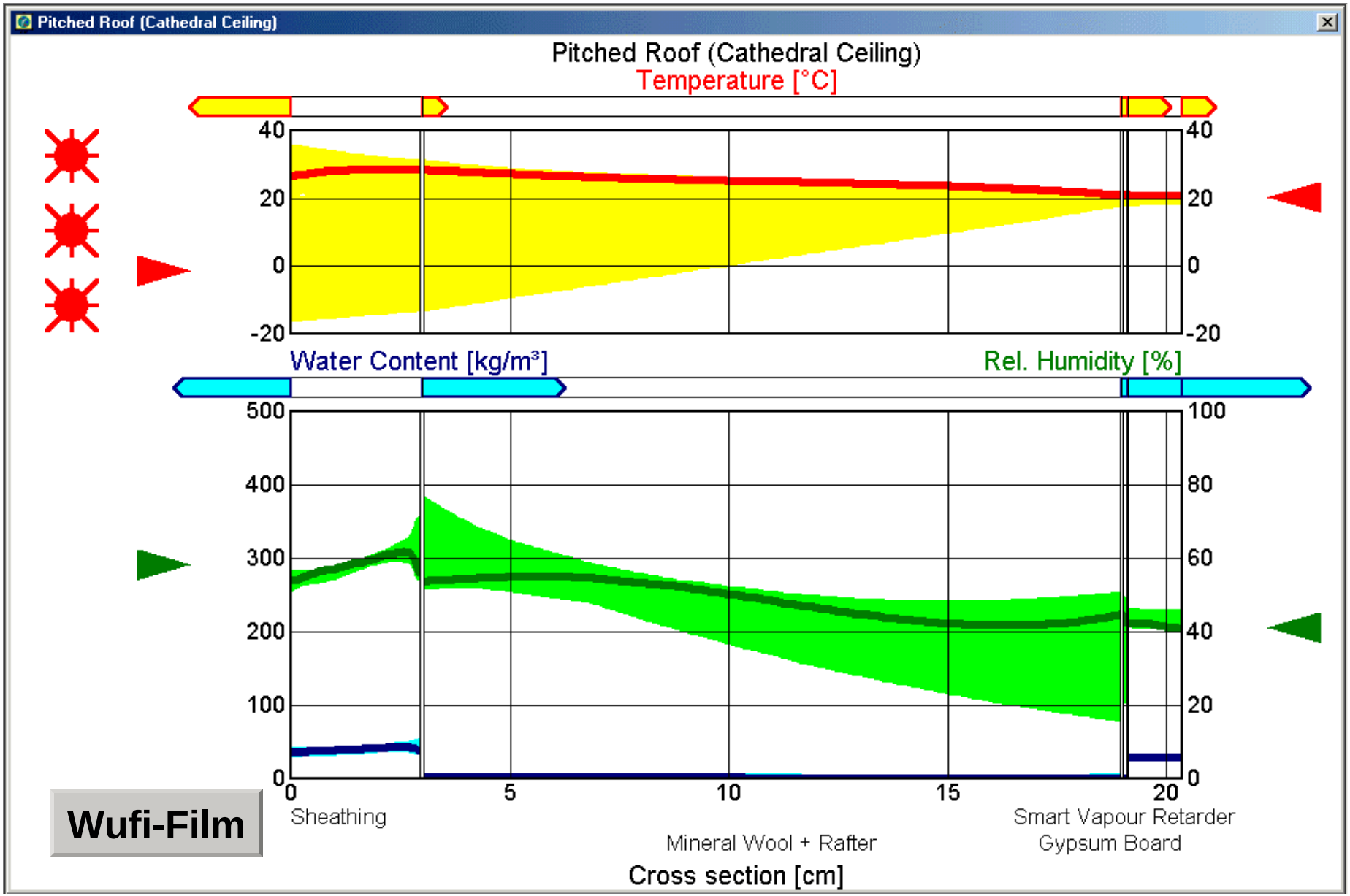


- Moisture Sensors

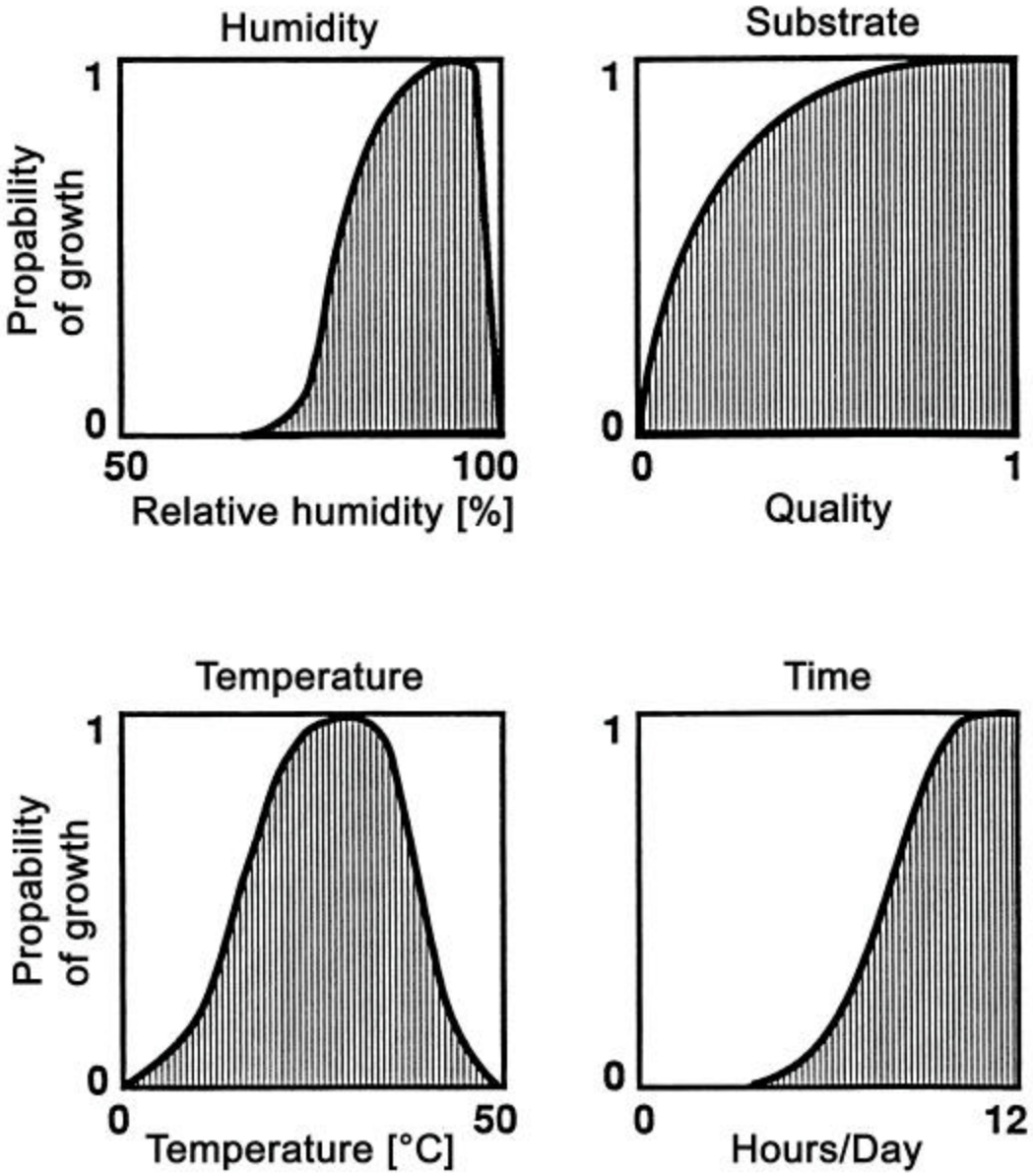
Mold growth due to summer condensation

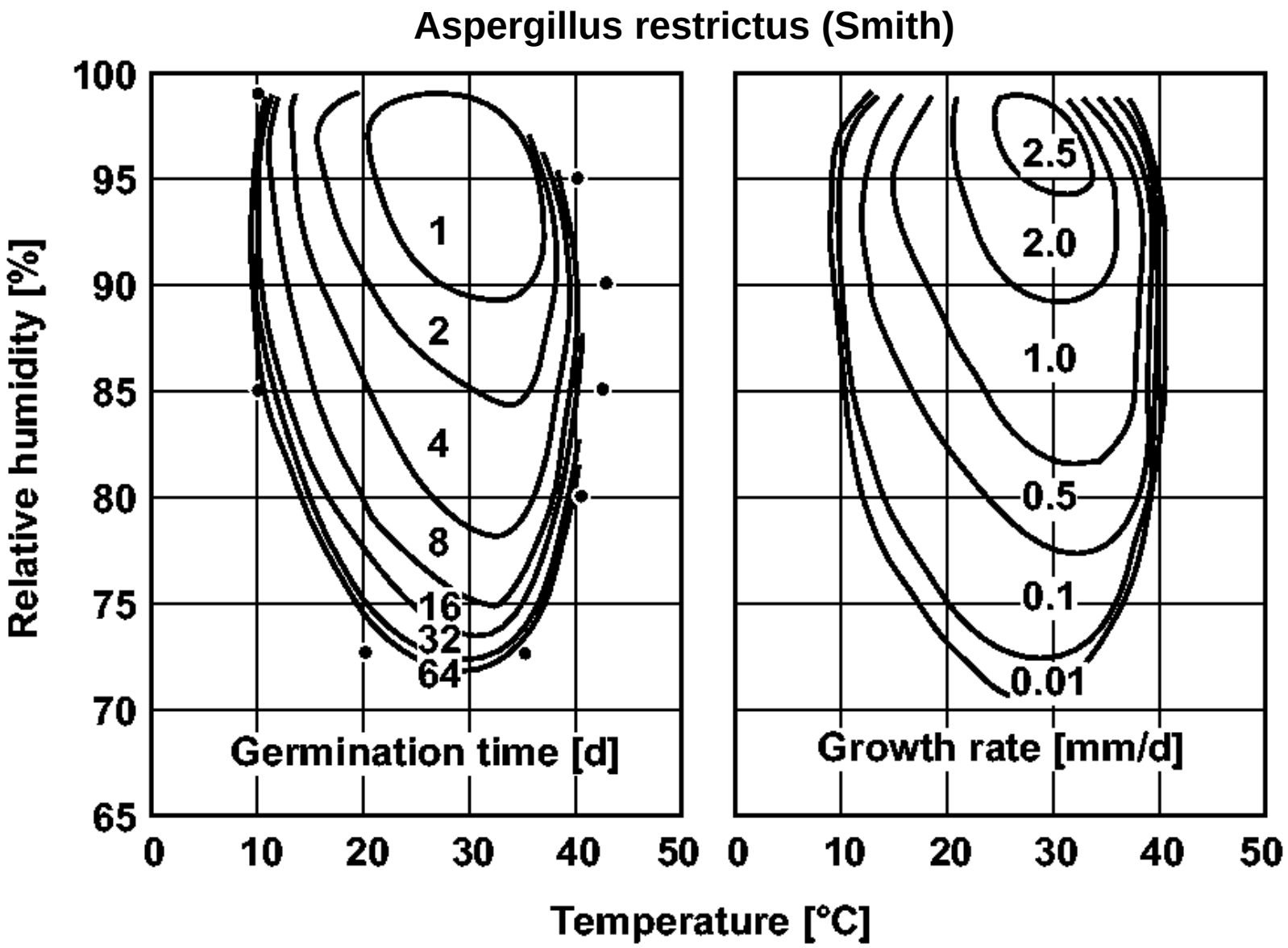
No Mold growth on PA-Film

Computational Analysis of the Hygrothermal Conditions



Factors Favoring Mold Growth

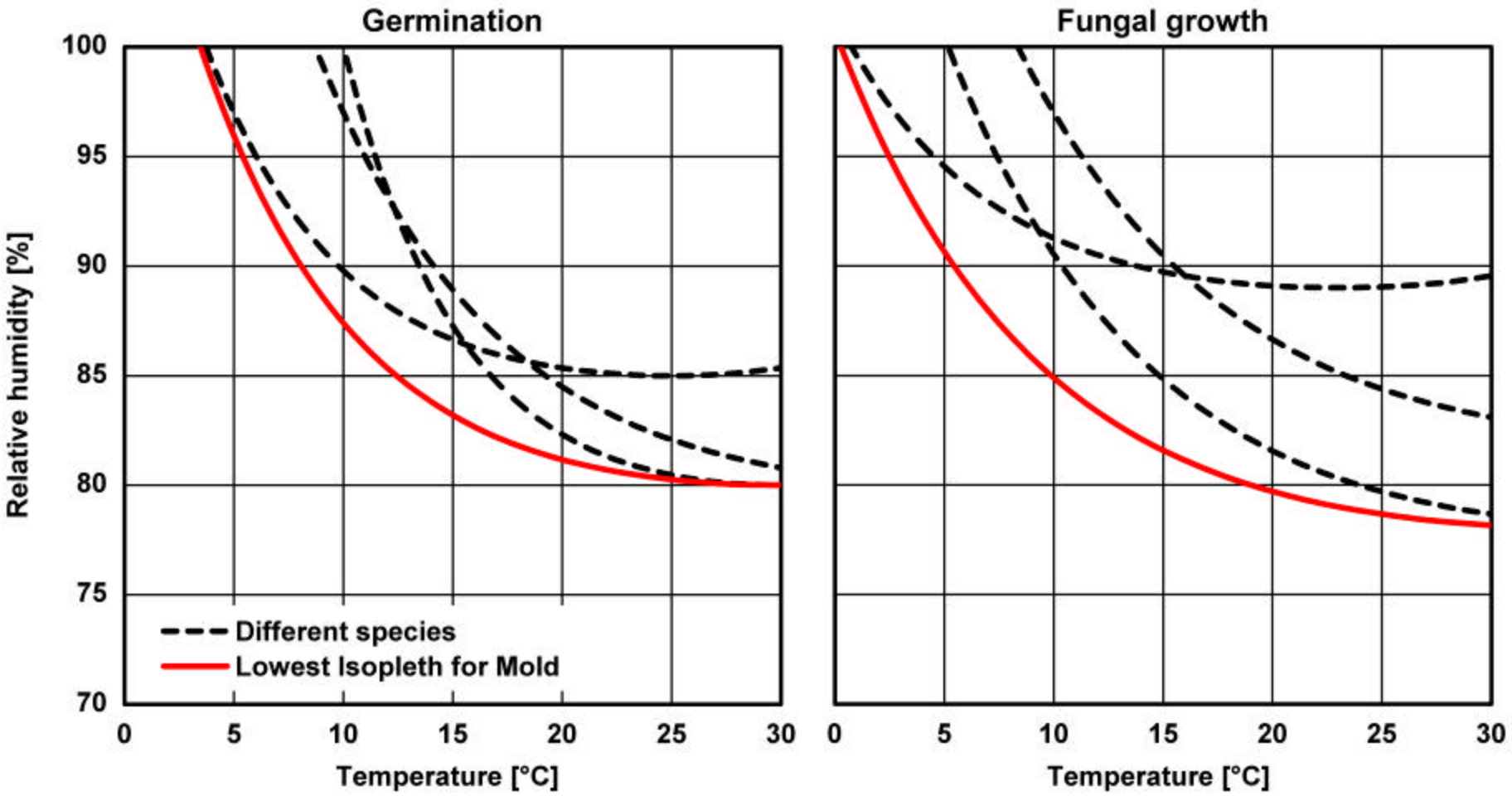



Aspergillus restrictus (Smith)
Relative humidity [%]
100
95
90
85
80
75
70
65
1
2
4
8
16
32
64
Germination time [d]
2.5
2.0
1.0
0.5
0.1
0.01
Growth rate [mm/d]
0
10
20
30
40
50
Temperature [°C]

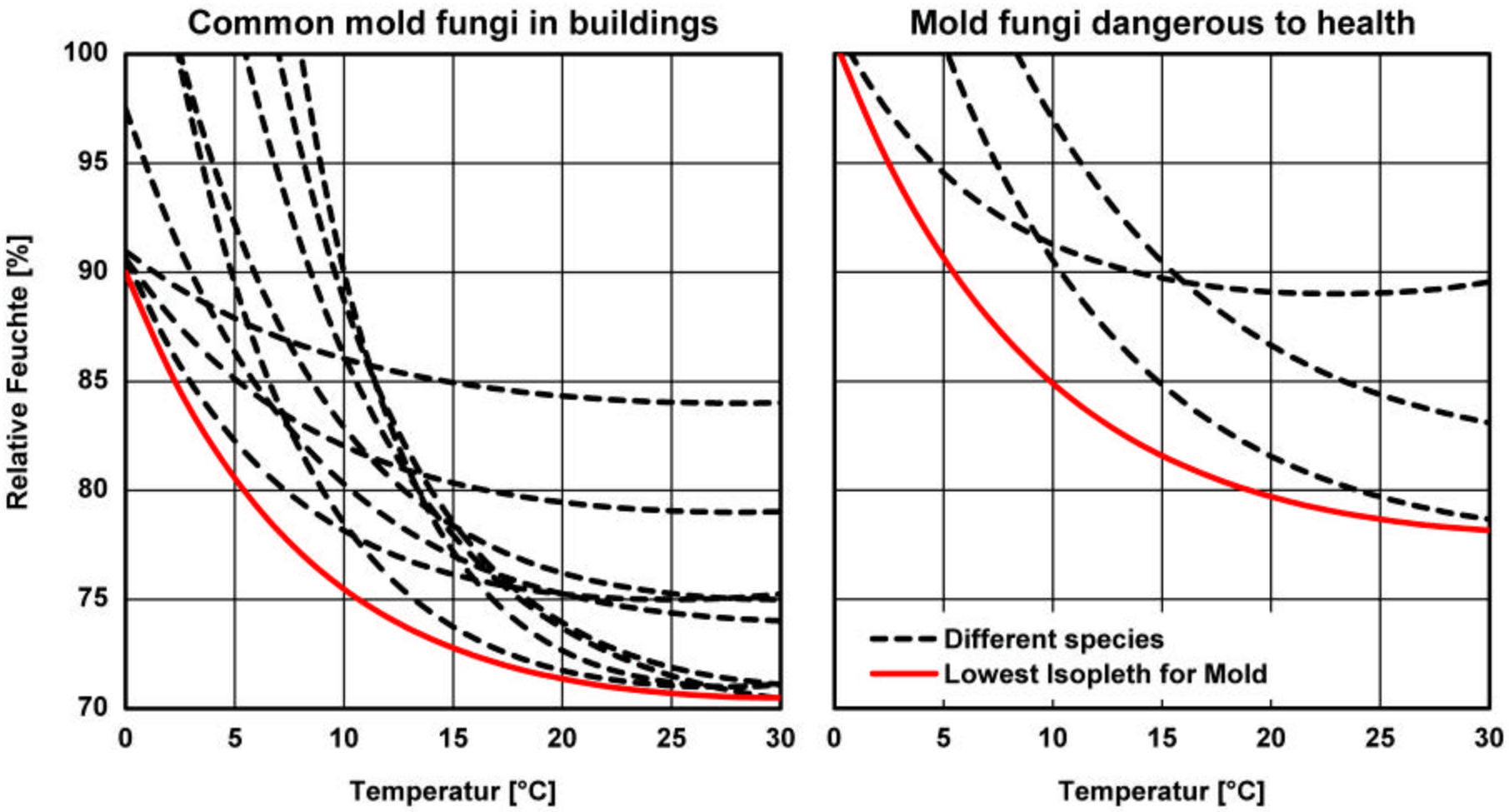
Development of the Lowest Isopleth for Mold

Mold fungi considered as dangerous to health:

(Aspergillus fumigatus, Aspergillus flavus, Stachybotrys chartarum)

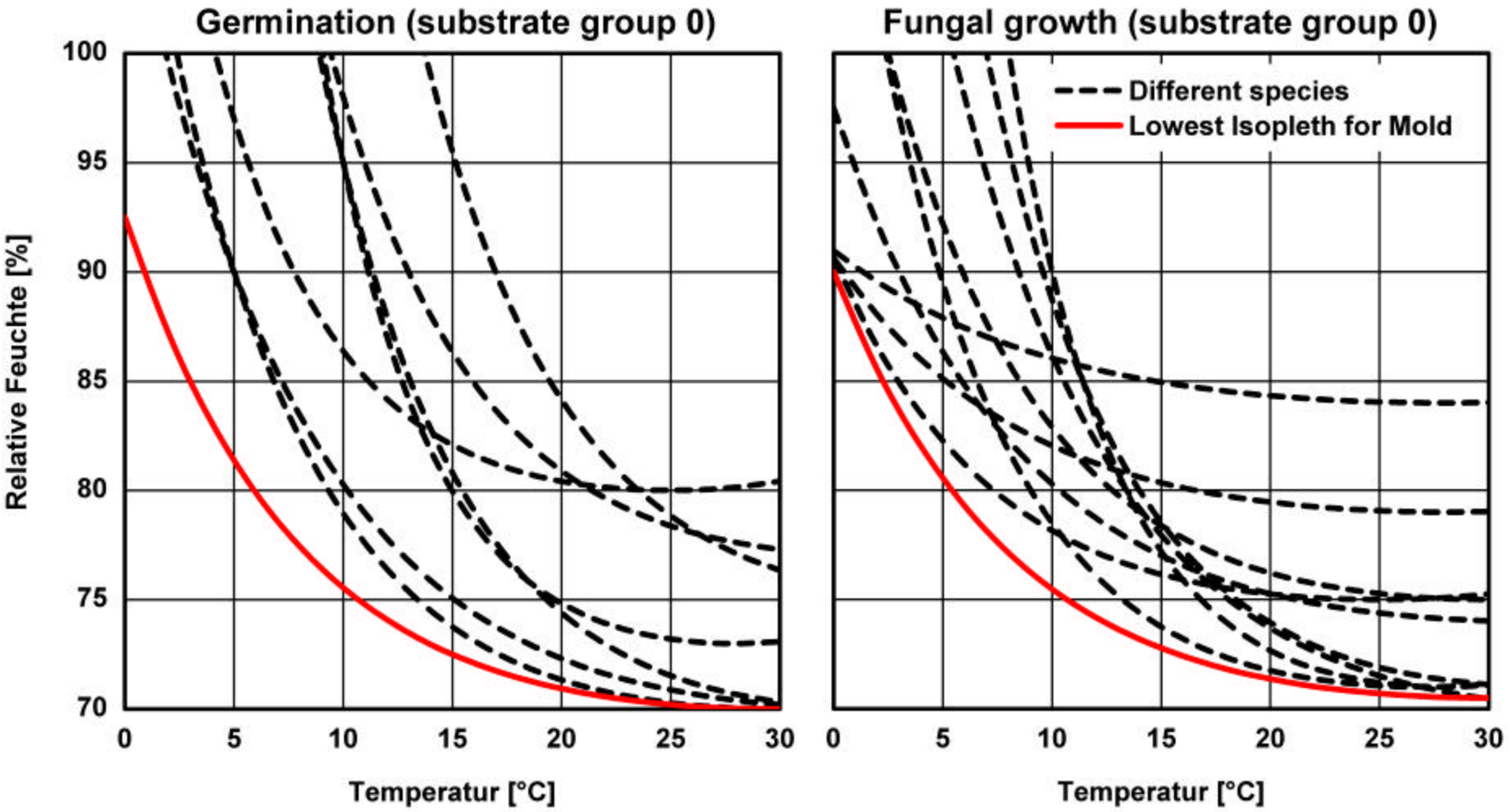


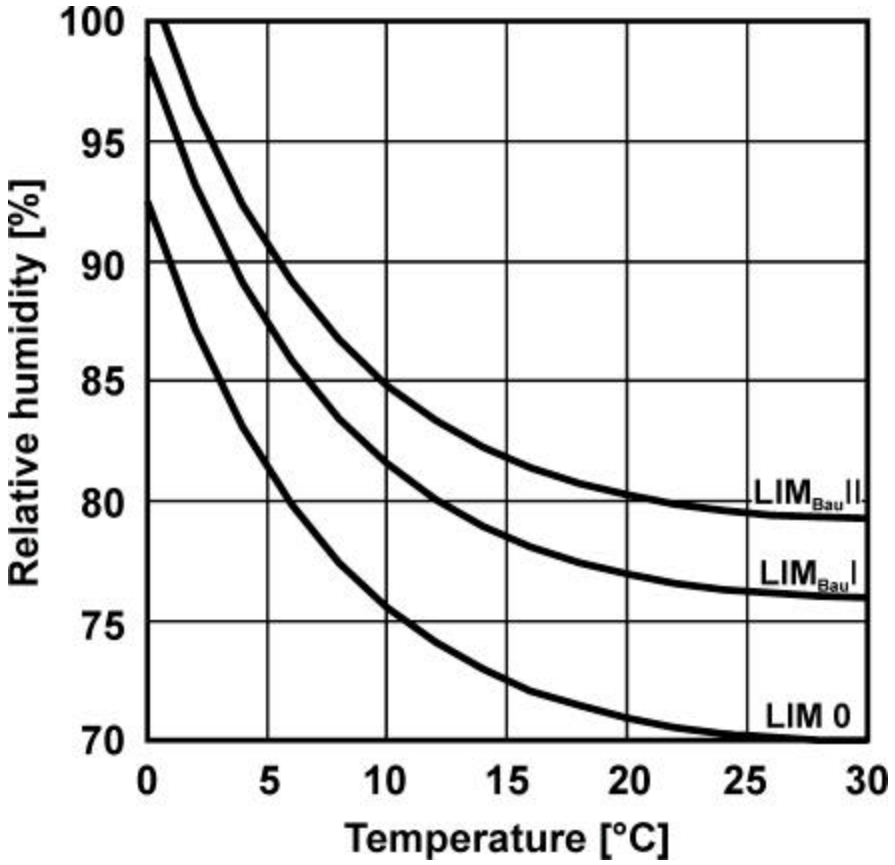
Development of the Lowest Isopleth for Mold



Fortunately higher humidity necessary for mold with health risk

Development of the Lowest Isopleth for Mold





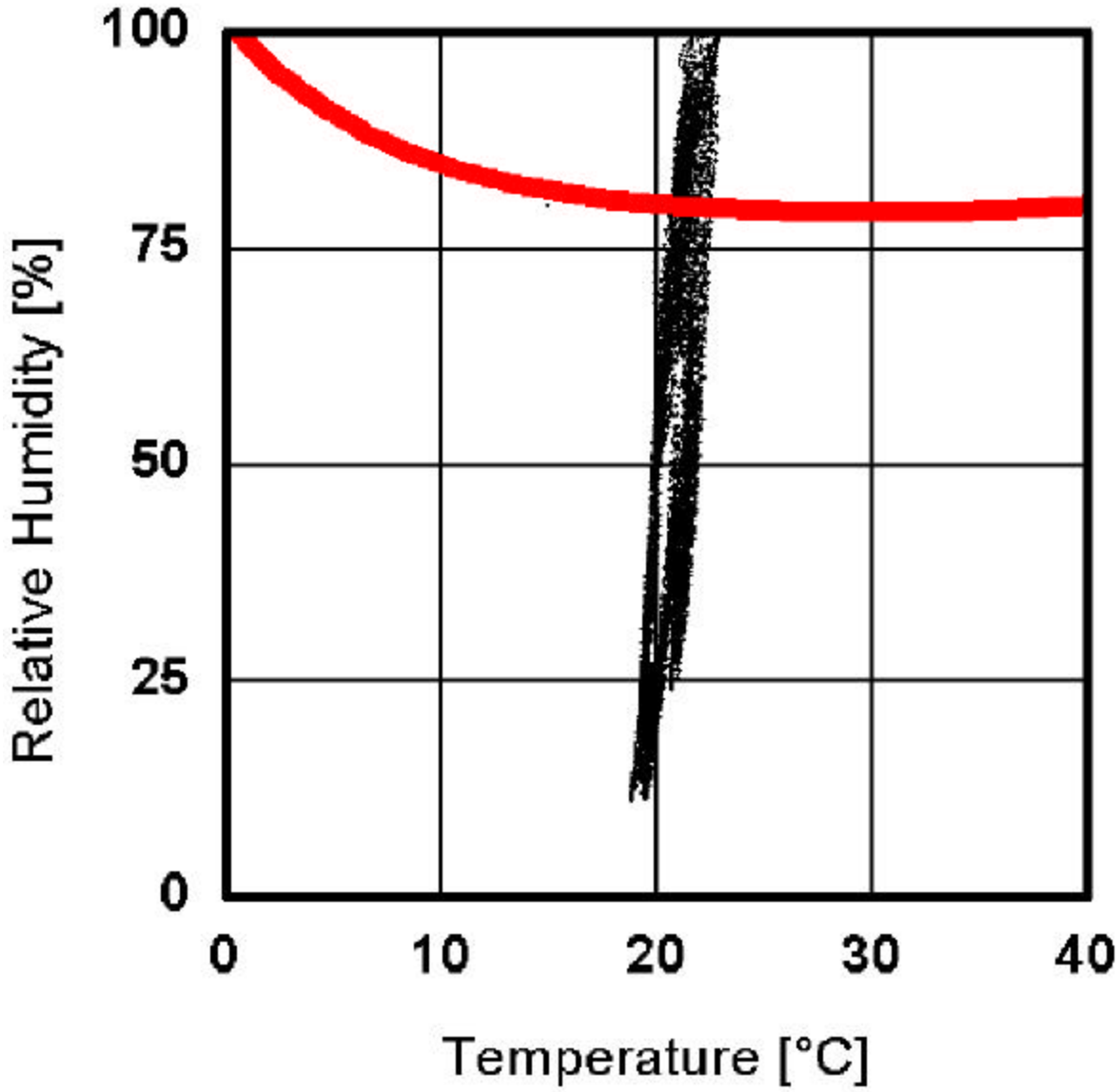
Substrate group:

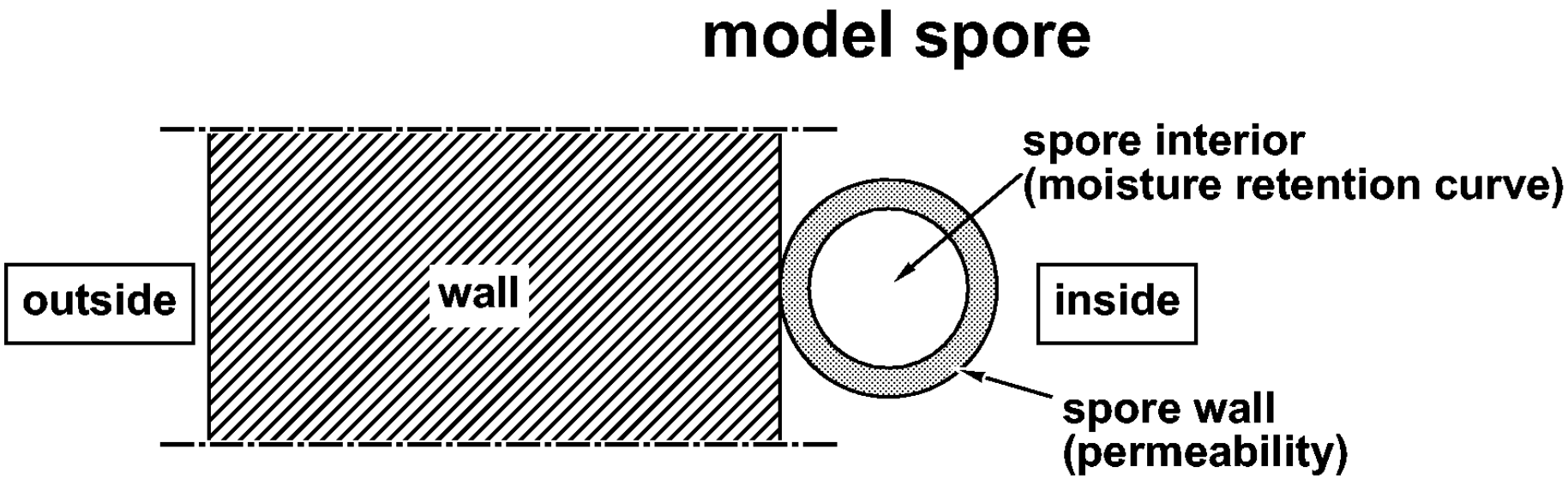
0 optimum substrate
(biological full medium)

I biodegradable substrates
(wood, wall paper, ...)

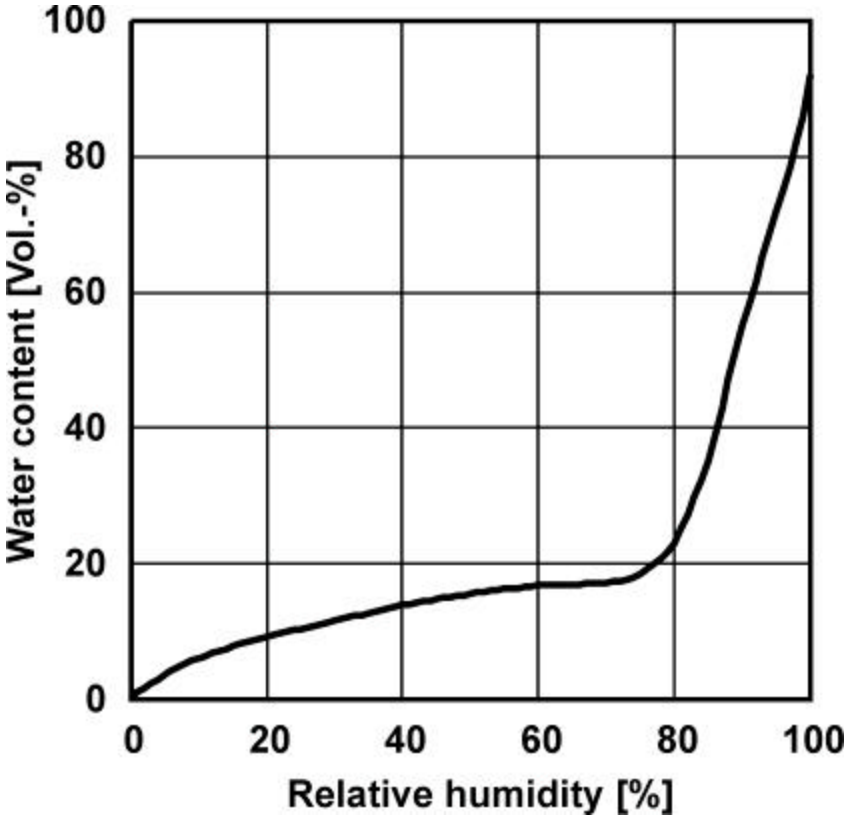
II non biodegradable substrates
(mineral building materials)

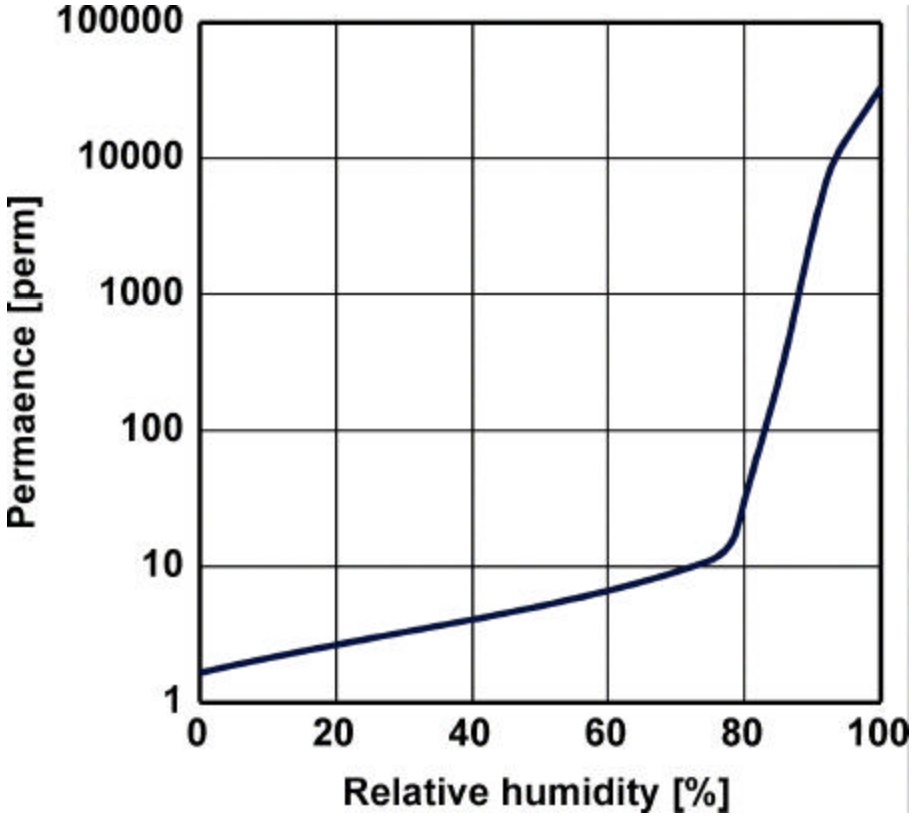
Hygrothermal Simulation of Cathedral Ceiling Conditions




model spore
spore interior
(moisture retention curve)
outside
wall
inside
spore wall
(permeability)

Hygrothermal Characteristics of the Model Spore





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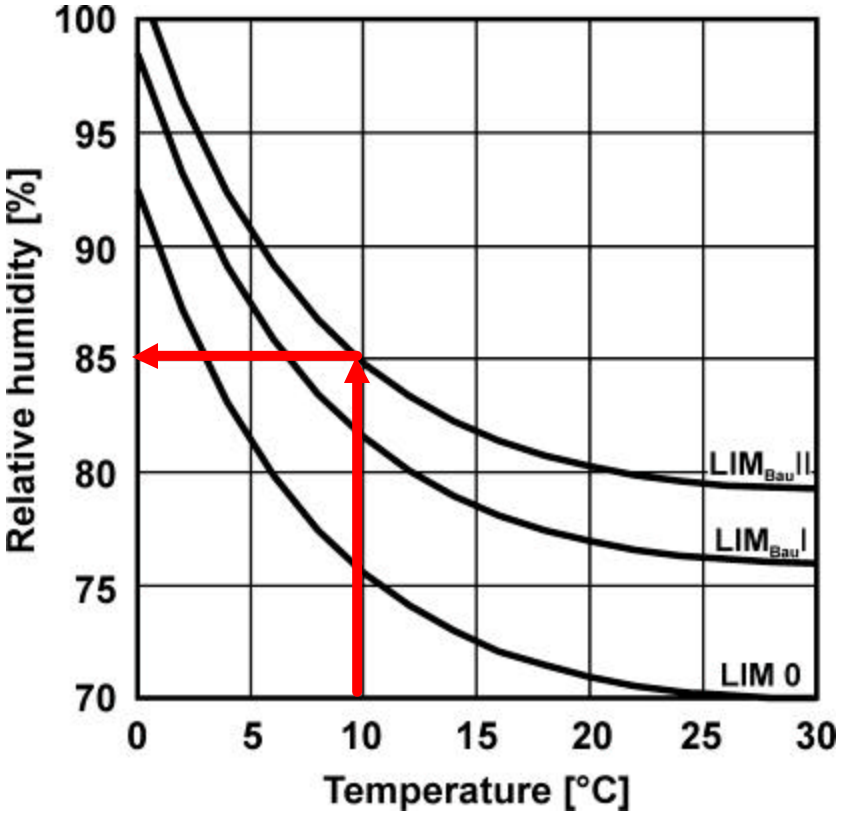
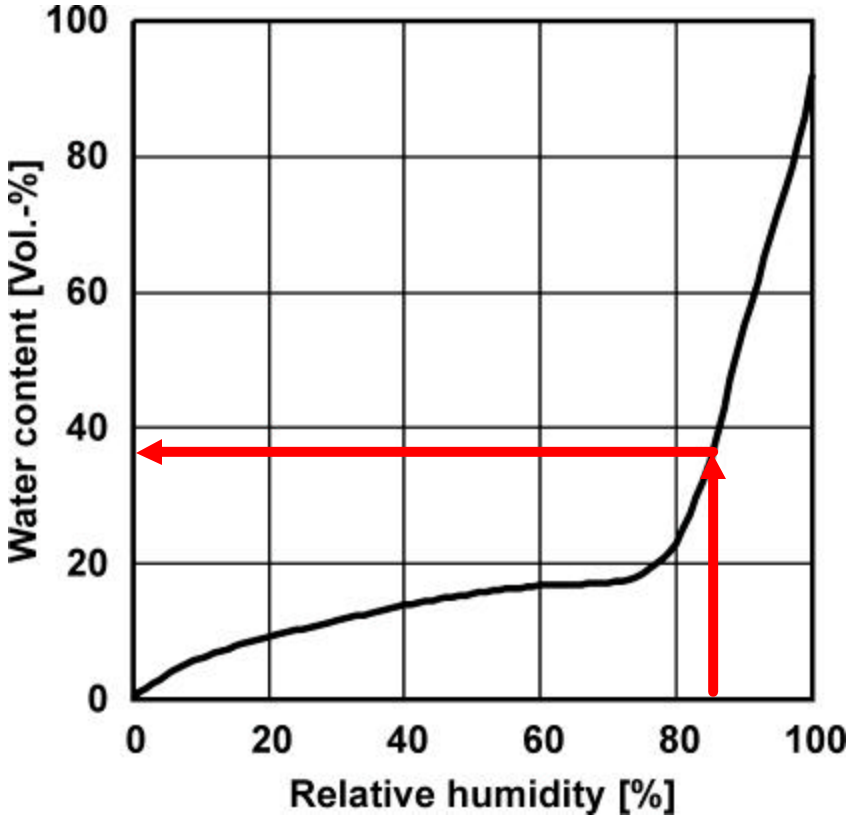
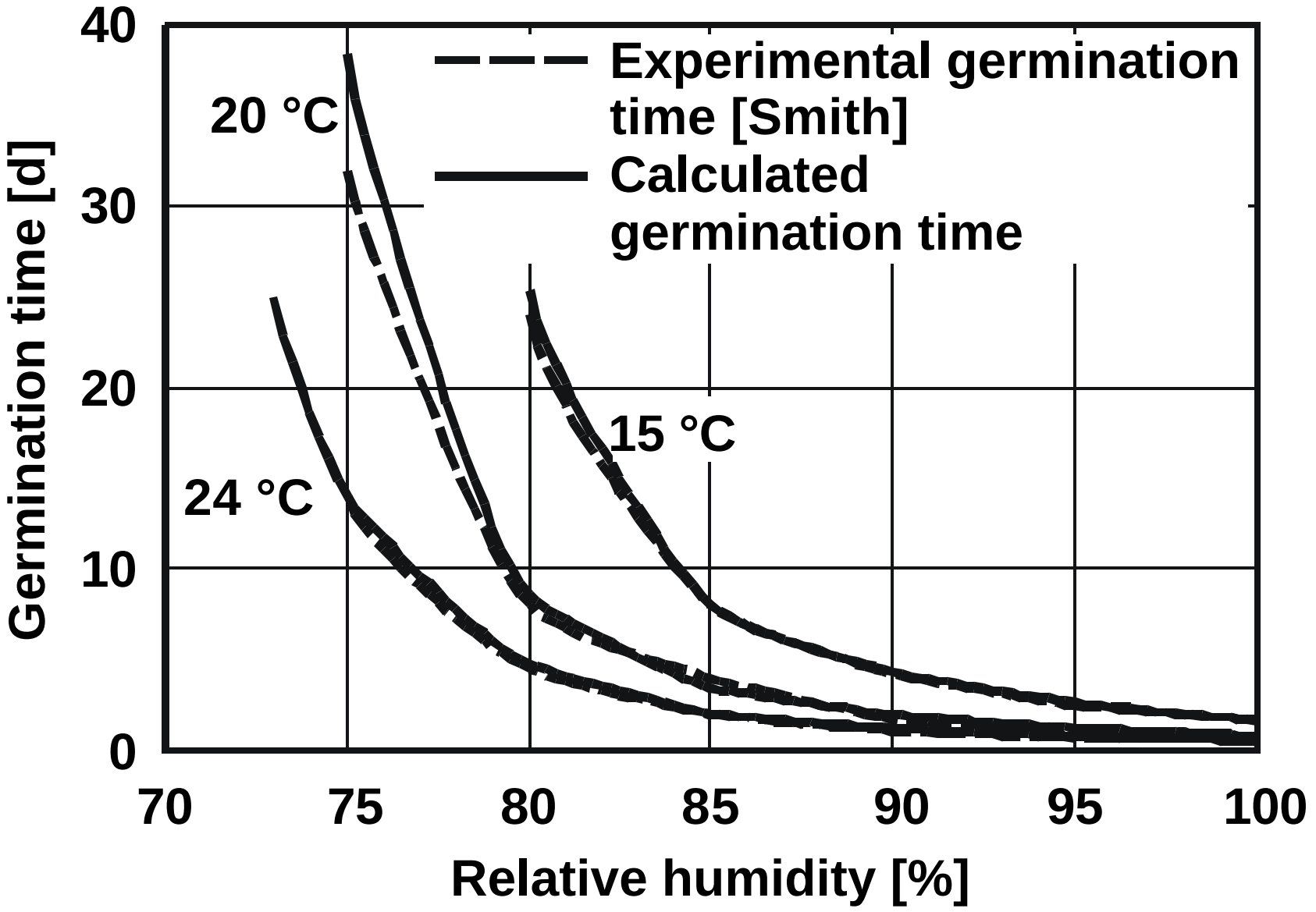
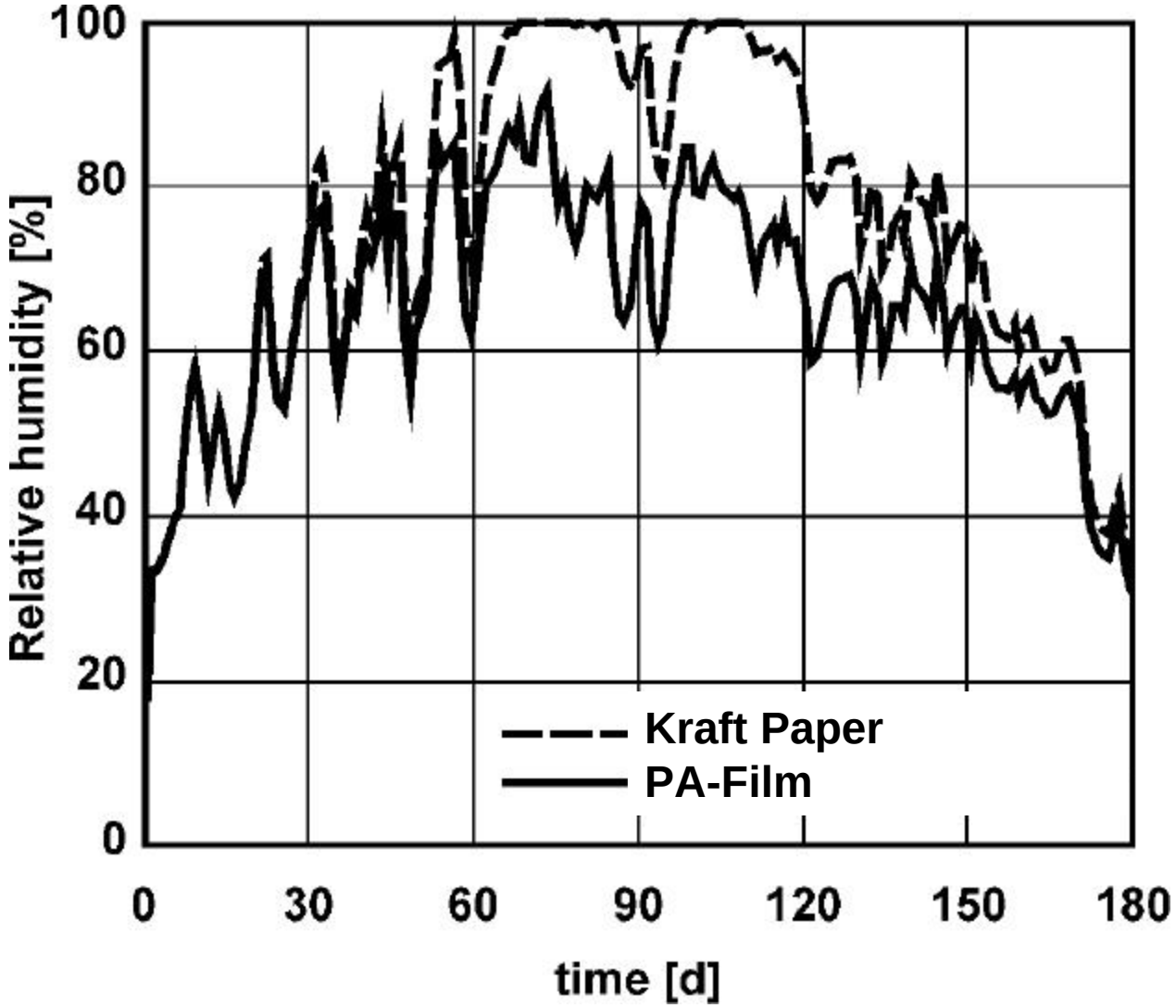
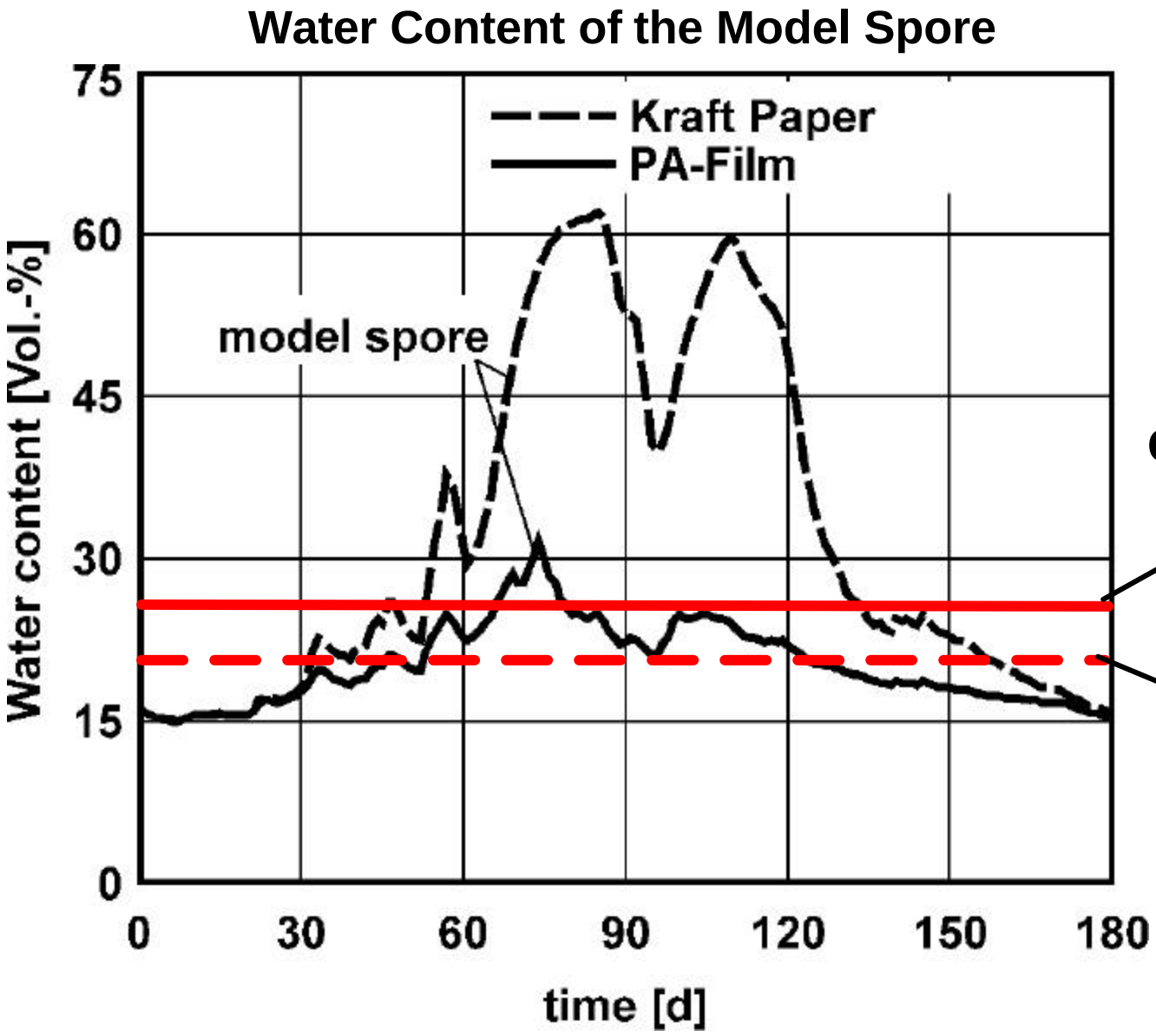





Experimental germination time [Smith]
Calculated germination time
20 °C
15 °C
24 °C
Germination time [d]
0
10
20
30
40
70
75
80
85
90
95
100
Relative humidity [%]

Humidity Behind the Vapor Retarder





Critical Watercontent

non biodegradable substrate

biodegradable substrate

Summer condensation may lead to mold formation in the building envelope

Remedies:

- reduce moisture intrusion
- enhance drying potential
- avoid biodegradable materials in condensation planes

Mold growth predictions for fluctuating hygrothermal conditions

- new biohygrothermal model looks promising
- more research necessary to validate this model

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