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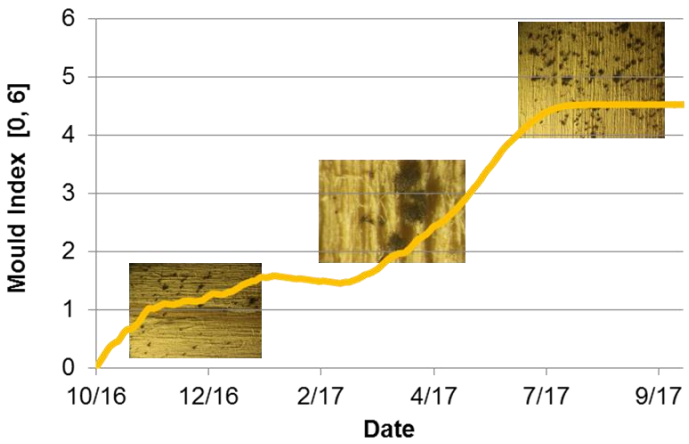


VTT Mold Model - From visual findings to mold index

Buildings XIII Workshop

How to Evaluate the Risk of Mold Using the Mold Growth Index

Tuomo Ojanen & Hannu Viitanen

Contents

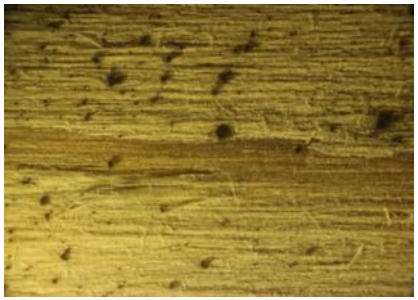
- Motivation for the work
- Laboratory experiments and their analysis
- Setting the Mold Index
- Model for wood and other building materials
- Applications

Background and motivation for the mold model

- Mold growth is one of the first signs of too high moisture content in (building) materials
  - It may affect the indoor air quality and the appearance of surfaces
  - Increasing moisture may lead to structural damages

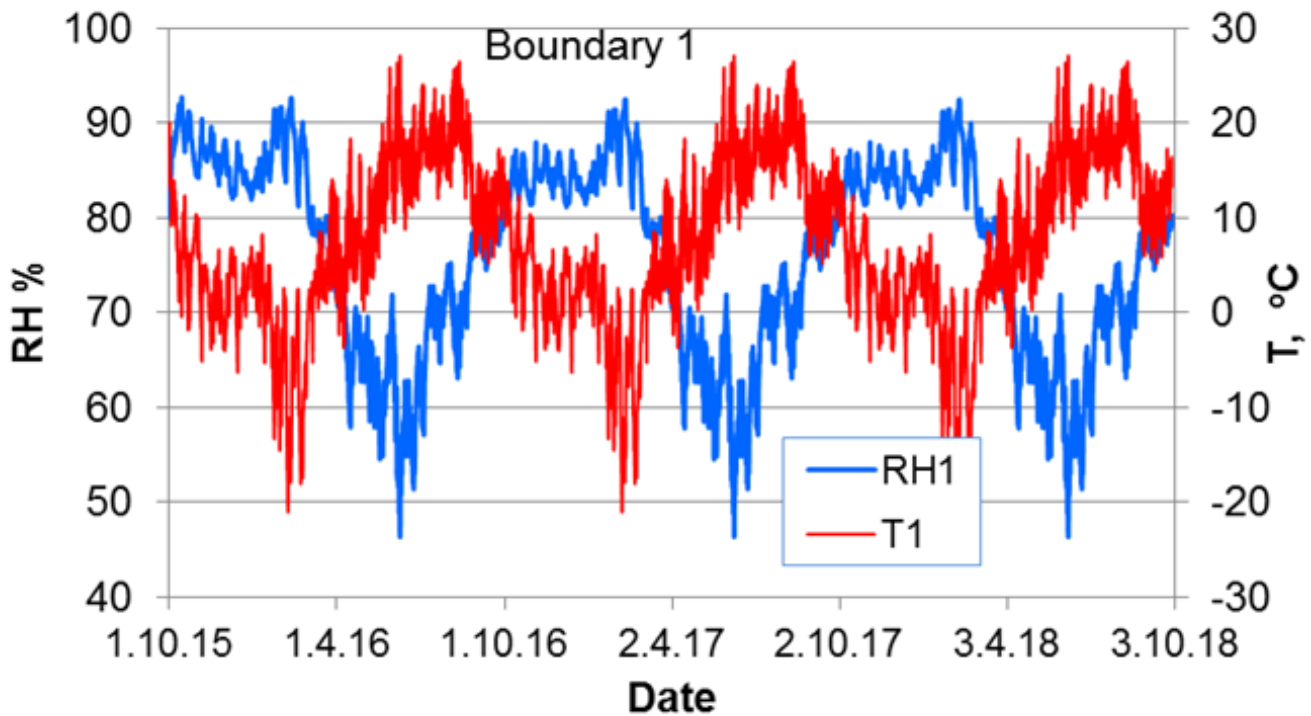
- natural ageing
  - grey wood
    - mould
      - indoor air
      - structures
        - VOCs
        - aestetics
          - load exceeds tolerance
            - decay
              - damage

Service life of buildings



Measured or numerically solved relative humidity and temperature values – Risk or not?

- Need for deeper analysis of the conditions and time of exposure for different materials



Motivation - Moisture performance criteria

- One single RH level is not enough as a criteria
- Need to take into account temperature, RH and time
- Hannu Viitanen started experiments with wood - Most sensitive building material to biological growth
- Work started already in 1990's
- Mold model for wooden material published in 1999

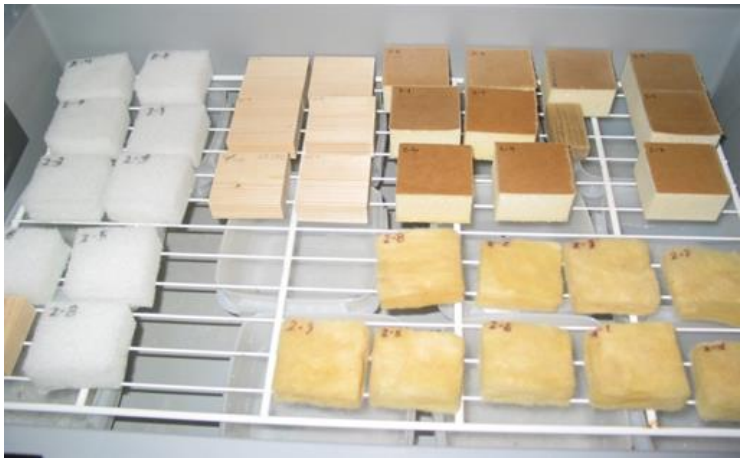
Hukka, Antti; Viitanen, Hannu. 1999. A mathematical model of mould growth on wooden material. Wood Science and Technology, vol. 33, 6, ss. 475 - 485

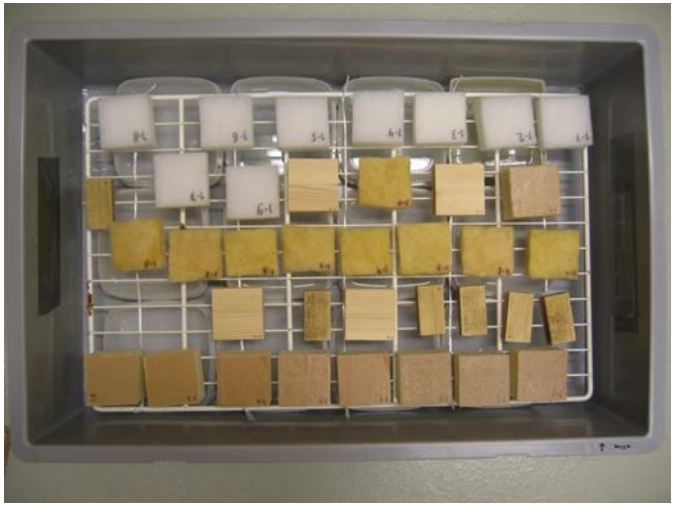
Mold Index

- Mold growth potential can be predicted by solving a numerical value, MOLD INDEX
- Values between [0, 6] depending on the growth coverage

Experiments under laboratory conditions

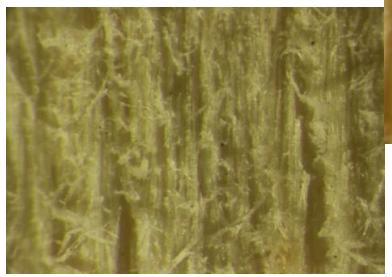
- Constant or cyclic conditions



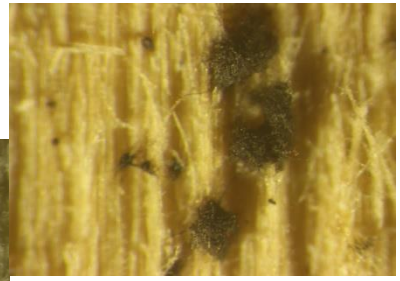


Mold Index levels on wooden surface

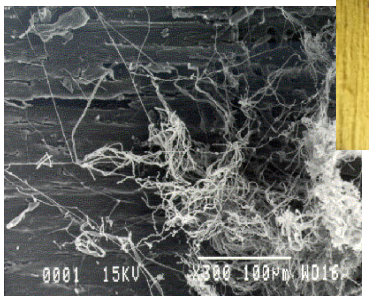
Set Mold Index level [0, 6] based on visual findings



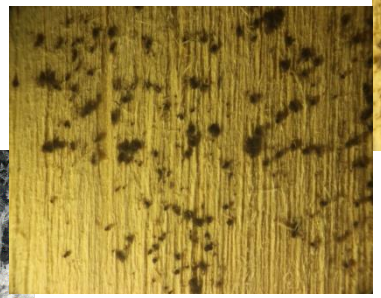
Index 1 (start of growth, wood)



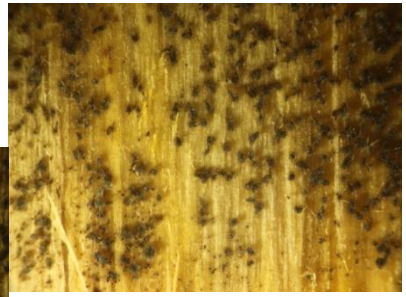
Index 3 - 4, wood,



Index 4, wood,



Index 5, wood,

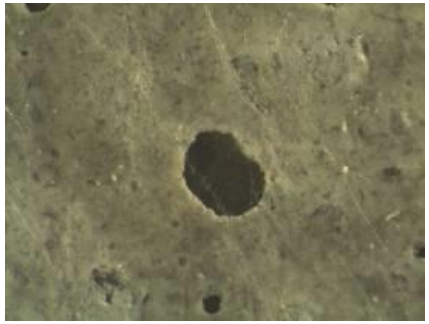


Index 6, wood

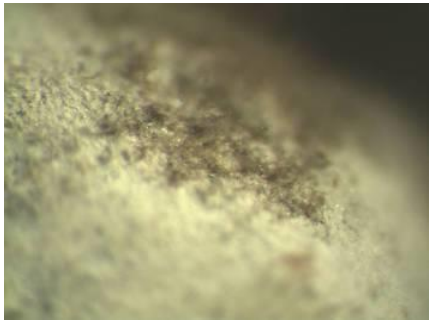
Increasing growth level

Mold Index levels on concrete surface

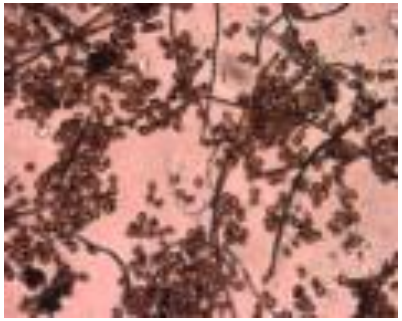
Set Mold Index level [0, 6] based on visual findings



Index 2, concrete



Index 3, concrete



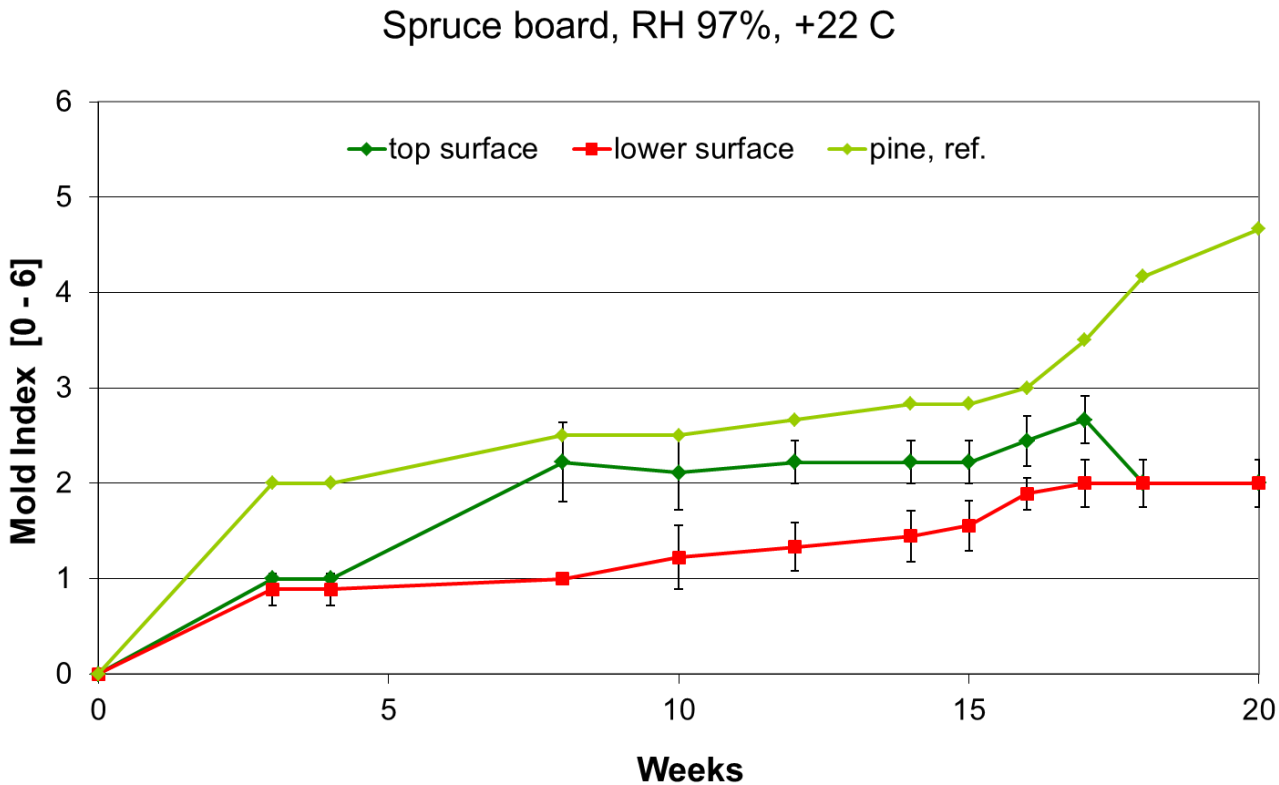
Index 5, concrete

Index 6, concrete

Increasing growth level

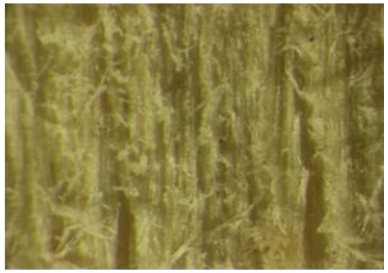
Interpretation of visual findings

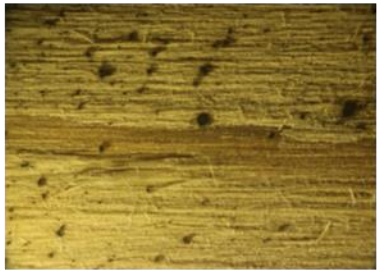
- Typically several (5 – 9) parallel samples
- Maximum, mean, upper quarter or average value for the index?
- Average values used

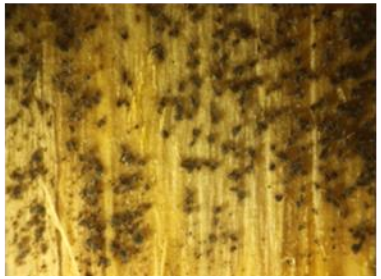


Mold index levels and definitions - Visual findings interpreted as mold index values

Index	Description of the growth rate
0	No growth
1	Small amounts of mould on surface (microscope), initial stages of local growth
2	Several local mould growth colonies on surface (microscope)
3	Visual findings of mould on surface, < 10 % coverage, or, < 50 % coverage of mould (microscope)
4	Visual findings of mould on surface, 10 - 50 % coverage, or, >50 % coverage of mould (microscope)
5	Plenty of growth on surface, > 50 % coverage (visual)
6	Heavy and tight growth, coverage about 100 %







Mold growth model for wood (spruce, pine)

- Forms the basis solver for all materials

$$M = \exp(-0.68 \ln T - 13.9 \ln RH + 0.14W - 0.33SQ + 66.02)$$

$$\frac{dM}{dt} = \frac{1}{7 \cdot \exp(-0.68 \ln T - 13.9 \ln RH + 0.14W - 0.33SQ + 66.02)} k_1 k_2$$

Regression model on mould growth based on laboratory studies

$$k_1 = \begin{cases} 1, \text{ when } M < 1 \\ \dfrac{2}{t_v / t_m - 1}, \text{ when } M > 1 \end{cases}$$

Growth at different stage

$$k_2 = \max\left[1 - \exp\left[2.3 \cdot (M + M_{\max})\right], 0\right]$$

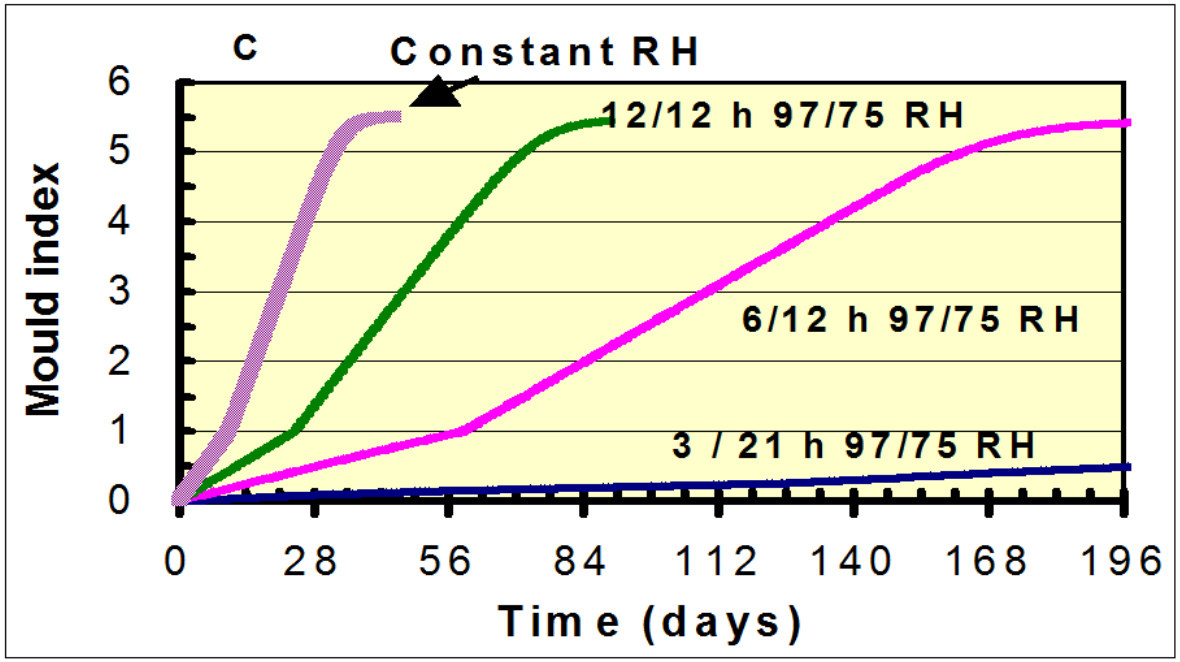
Retardation of the growth in the later stages

$$\frac{dM}{dt} = \begin{cases} -0.032, \text{ when } t - t_1 \le 6 \text{ h} \\ 0, \text{ when } 6 \text{ h} \le t - t_1 \le 24 \text{ h} \\ -0.016, \text{ when } t - t_1 > 24 \text{ h} \end{cases}$$

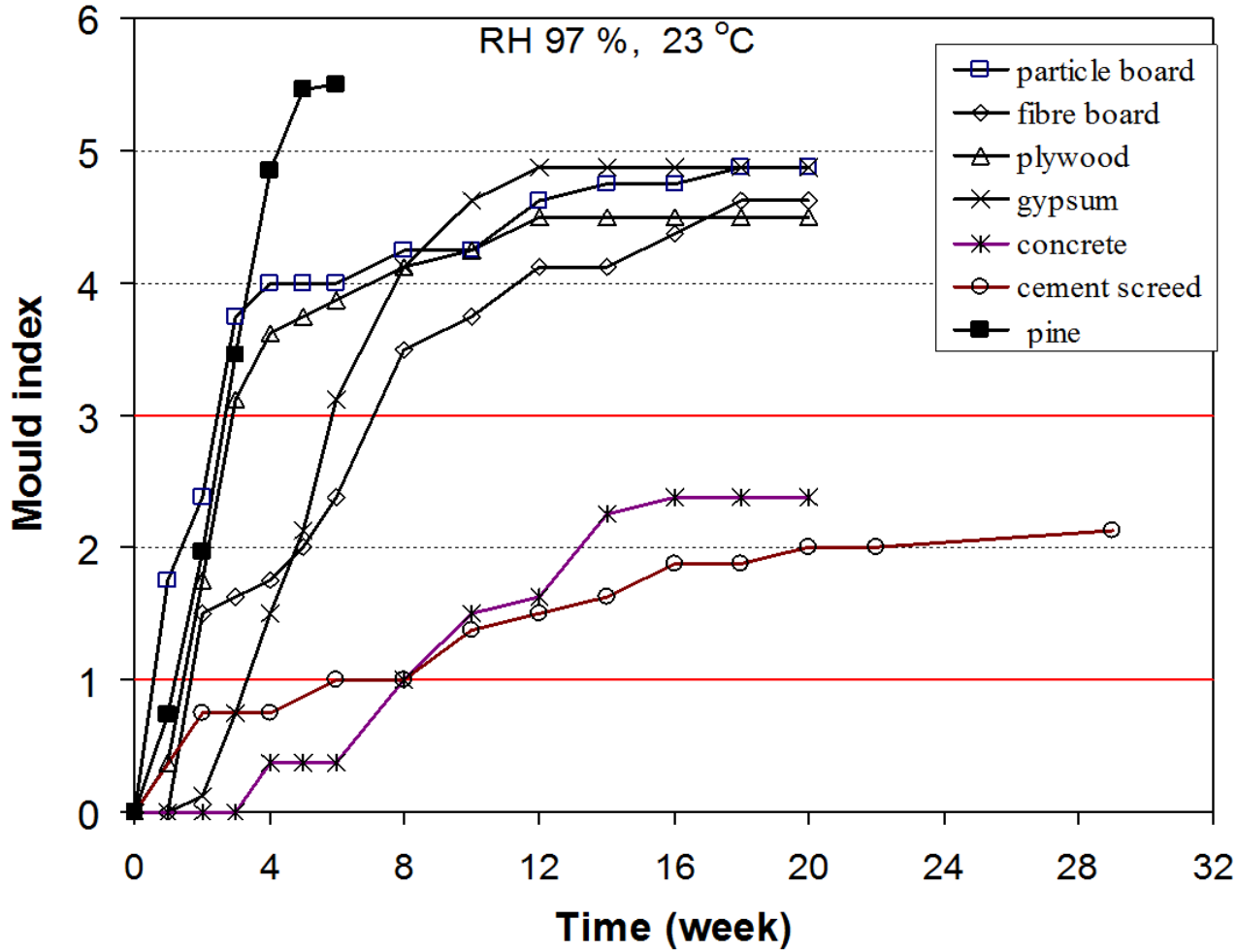
Delay of the growth

Mold growth under dynamic conditions

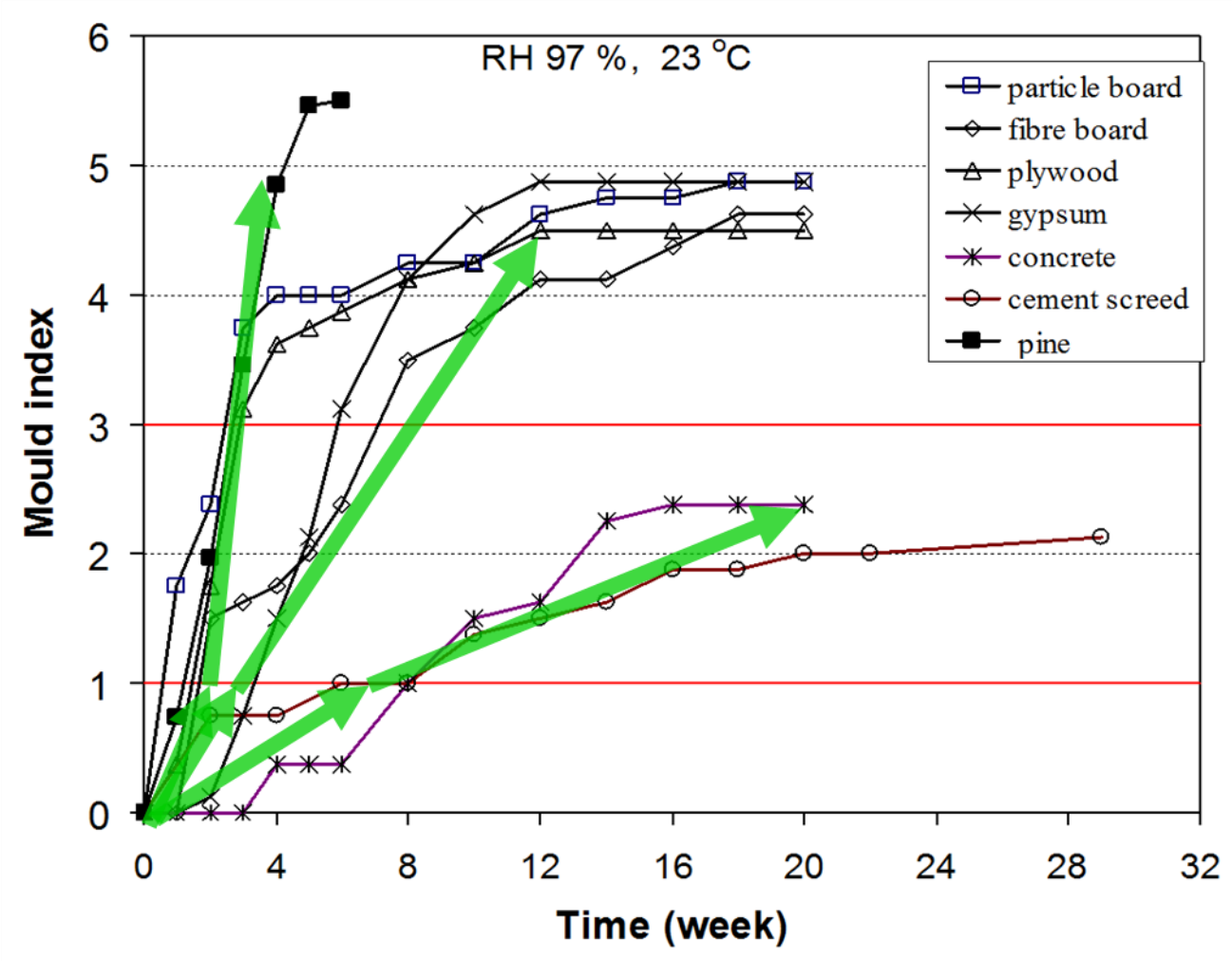
- Pine sapwood under cyclic humidity conditions: RH 97 % and 75 %
- Dynamic conditions slow down the growth due to:
  - Delays in surface humidity conditions
  - Effect on mold growth



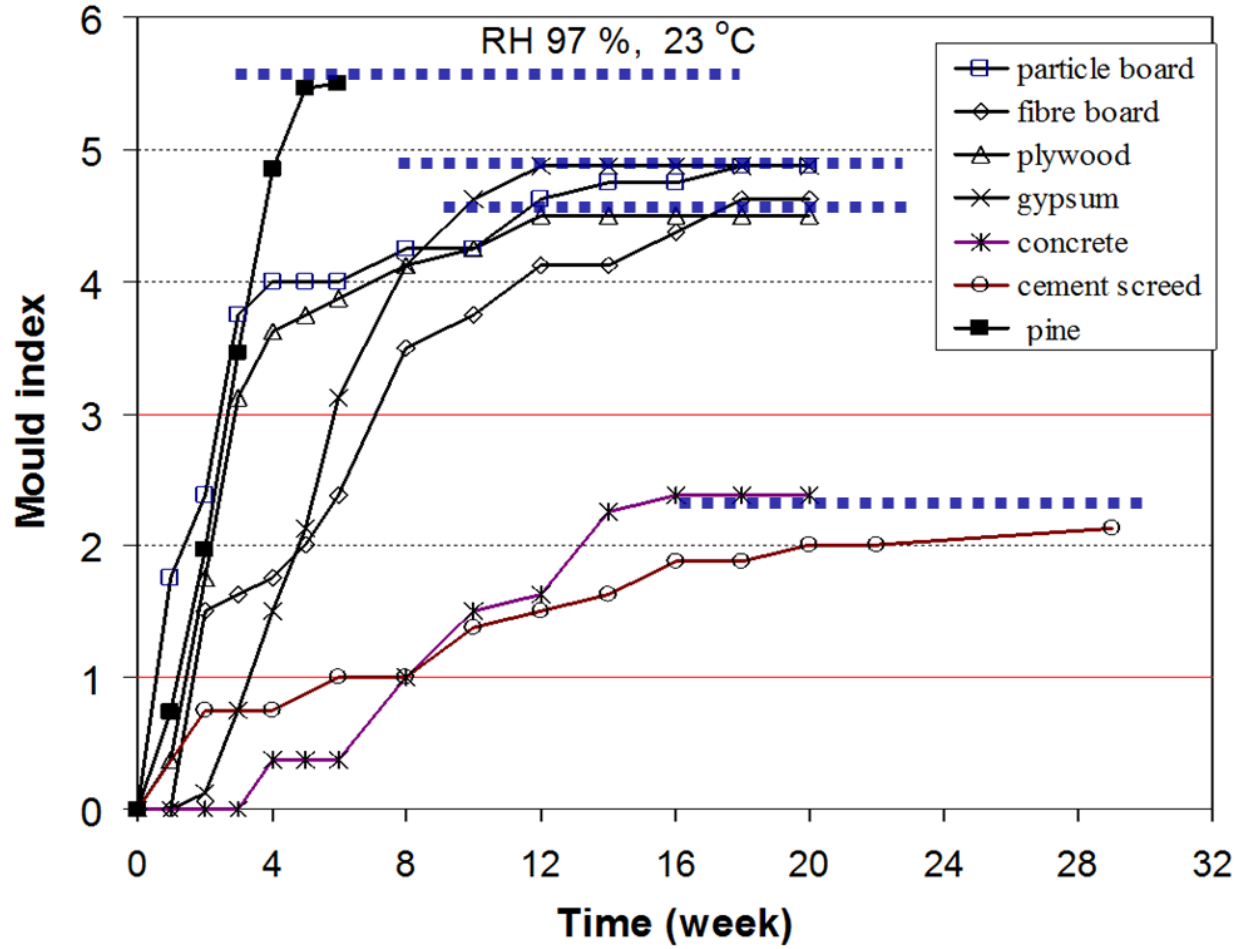
Different materials – Different growth intensity



Mold growth intensity classes



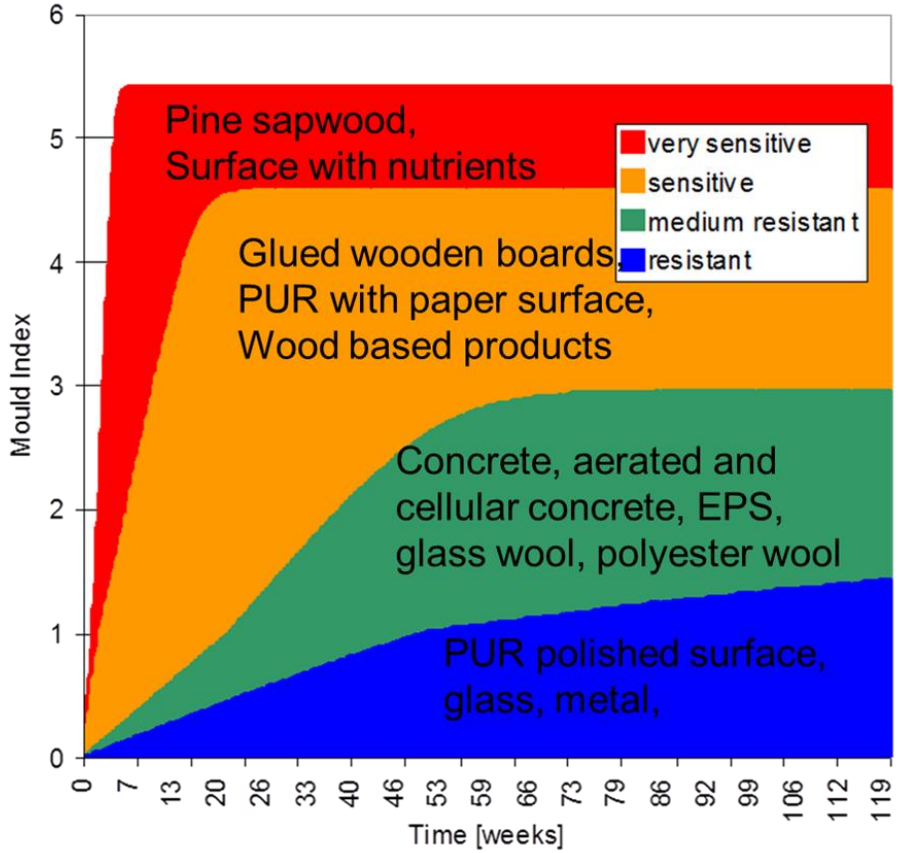
Maximum mold index levels under different conditions



Maximum levels of growth → Classification according material types

Mold sensitivity classes

- Set according to material mold test results
- Valid for tested materials – gives first approximation of mold growth sensitivity for materials/products



Peuhkuri, R; Viitanen, H; Ojanen, T. Modelling of mould growth in building envelopes Proceedings of the IEA ECBCS Annex 41 Closing seminar, Copenhagen, June 19, 2008

Same mold growth pattern for all materials

- The VTT Mold Growth Model can be applied to other building materials using scaling factors

VTT mold model equations - Reference material pine

$$\frac{dM}{dt} = \frac{1}{7 \cdot \exp(-0.68 \ln T - 13.9 \ln RH + 0.14W - 0.33SQ + 66.02)} k_1 k_2$$

$$k_1 = \begin{cases} \dfrac{t_{M=1,pine}}{t_{M=1}}, \text{when } M < 1 \\ 2 \cdot \dfrac{(t_{M=3,pine} - t_{M=1,pine})}{(t_{M=3} - t_{M=1})}, \text{when } M \geq 1 \end{cases}$$

$$k_2 = \max[1 - \exp[2.3 \cdot (M - M_{\max})], 0]$$

$$M_{\max} = A + B \cdot \frac{RH_{crit} - RH}{RH_{crit} - 100} - C \cdot \left(\frac{RH_{crit} - RH}{RH_{crit} - 100} \right)^2$$

Scaling factors k_1 and k_2 for different materials

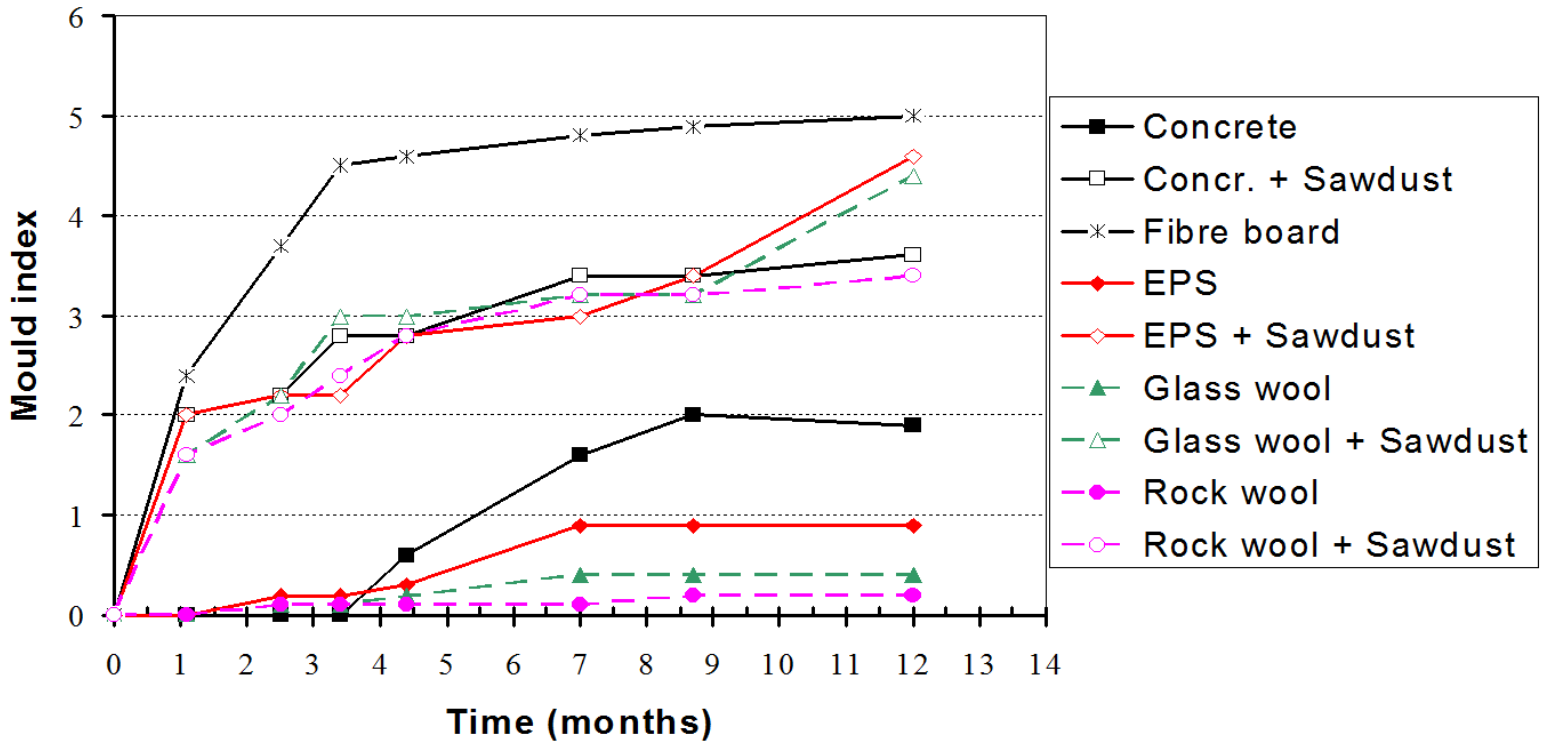
Coefficient k_1 is used to scale the growth intensity

Coefficient k_2 to limit the growth to maximum possible index level

More in model equation presentation …

Growth on soiled surfaces - 1

+20 C / 98 % RH conditions



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Effect of organic dust on surface

- Mold growth sensitivity of **soiled surface** approaches that of **pine**
- Pine model can be used to present the first risk approximation for mold growth of old and soiled material surfaces

VTT Mold Model - 1

- Model developed at VTT by Hannu Viitanen et. al.
- Based on building biotechnical know how
- Basic model applied for different materials using coefficients
- All modelling for different materials carried out by VTT
- Material sensitivity classes set in one collaboration project with Tampere University of Technology

VTT Mold Model - 2

- Model can be only as good as the data behind it:
  - Variations inside same materials / different products
  - Interpretation of mold index findings
  - Use material classification when product has not studied separately
- Best for **risk analysis**, exact simulations of growth seldom needed
- Does the index level cause risks to indoor air or correlate to other moisture problems for structures

VTT Mold Model – Some references

Viitanen, Hannu. The critical conditions causing mould and decay problems in buildings. User-oriented and Cost Effective Management, Maintenance and Modernization of Building Facilities, CIBW70 Helsinki '96 Symposium.Helsinki, 2 - 4 Sept. 1996. Association of Finnish Civil Engineers RIL. Helsinki (1996), 435 – 438

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Viitanen, Hannu; Ritschkoff, Anne-Christine; Ojanen, Tuomo; Salonvaara, Mikael. Moisture conditions and biodeterioration risk of building materials and structure. Proceedings of the 2nd International Symposium ILCDES 2003 Integrated Life-time Engineering of Buildings and Civil Infrastrucures, Kuopio, 1-3 Dec. 2003. RIL, VTT, CIB, RILEM, IABSE, ECCE, ASCE. Espoo (2003), 151 – 156

Viitanen, Hannu; Ojanen, Tuomo. Improved model to predict mould growth in building materials. Proceedings. Thermal Performance of the Exterior Envelopes of Whole Buildings X. Clearwater Beach, USA, 2 - 7 Dec. 2007. CD. ASHRAE, DOE, ORNL. Atlanta, USA (2007), 8

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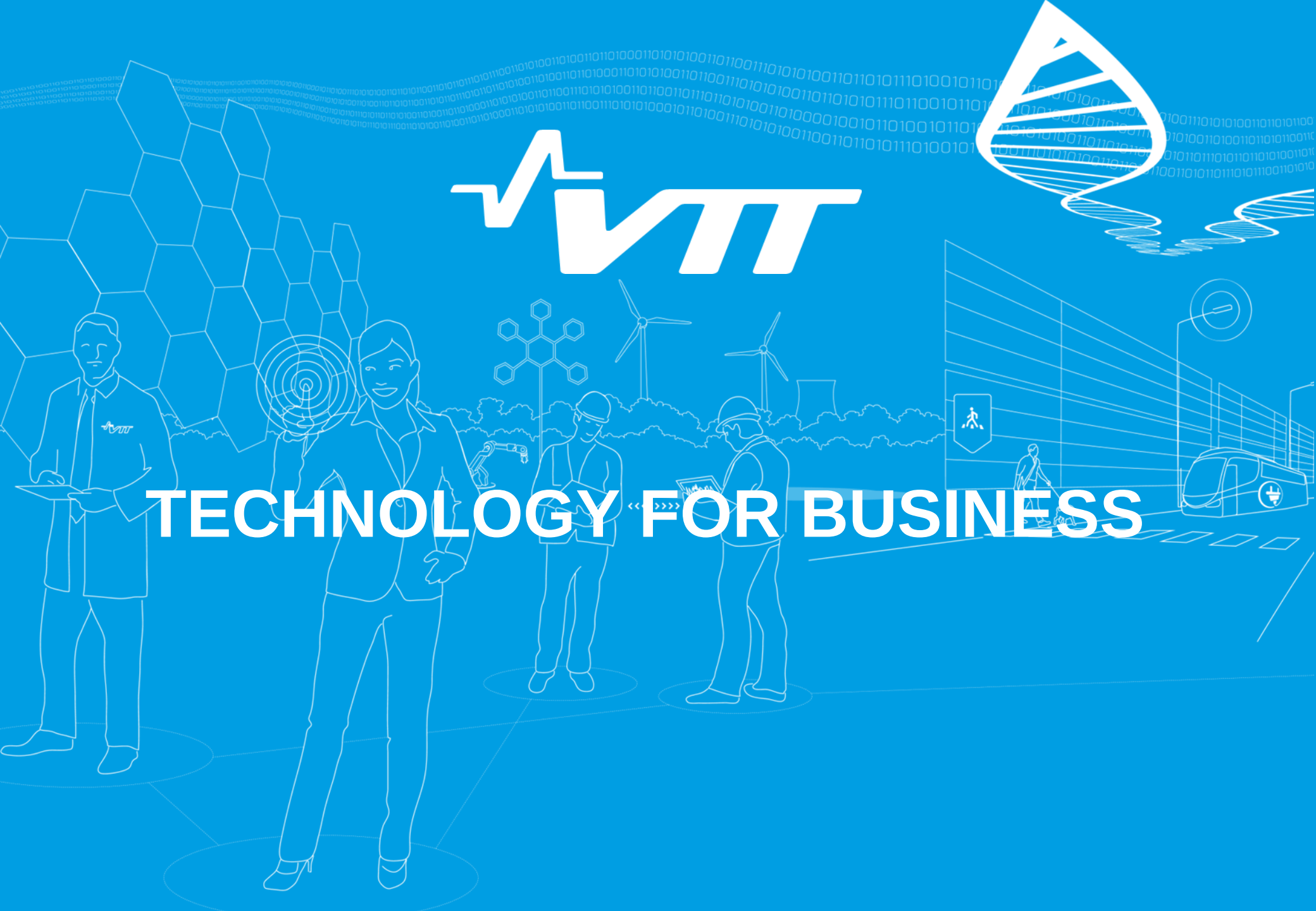
Ojanen, T., Viitanen, H., Peuhkuri, R., Lähdesmäki, K.,Vinha, J., Salminen, K. Mould growth modeling of building structures using sensitivity classes of materials. Proceedings (in CD) of the Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference, Dec 5.-9.2010. Clearwater Beach, Florida. 10 p.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