



Testing hygrothermal properties for information on durability?

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Bangor, UK

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Introduction

We've seen that;

- The use of alternative bio-based materials in building is on the increase.
- If a product is bio-based it runs the risk of microbial attack
- This may lead to structural, aesthetic or health problems.



How do you stop microbial attack?

Keep it dry!

The End

But really...

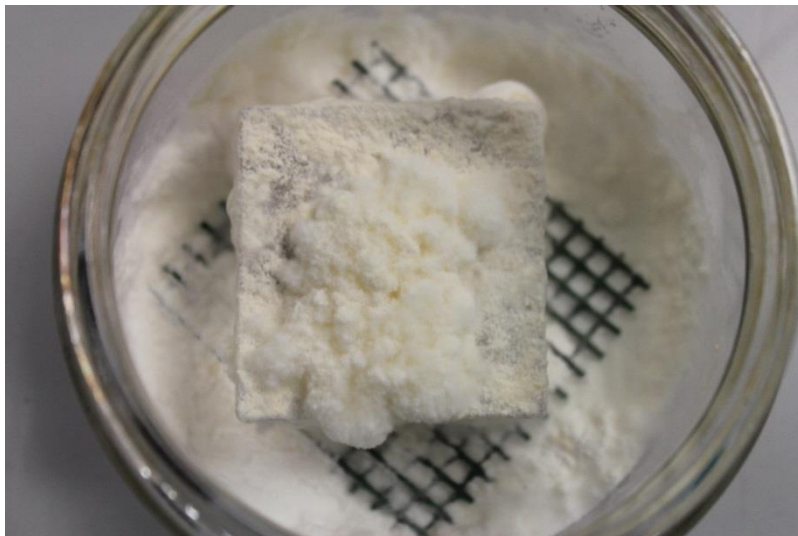


How do we test for durability vs biological attack

- Standard lab methods - Fast and reproducible
 - Mould tests – spore suspensions
 - Decay fungi - Agar block test
- Field tests – Time consuming



Fungal Exposure tests



Laboratory tests

- Normally provide plenty of moisture in terms of humidity and/or agar.
- Fast and reproducible
- **But...**Is this an appropriate test for modified wood?



Wood testing

- EN 113 tests used for preservative and natural durability tests states
 - *Discount any specimen having an MC of less than 25% at the end of the test.*



- But if the decay protection mechanism is the changed moisture relationship ...
 - Can we look at the hygrothermal properties to predict how a material will behave.



How dry is dry?

- What's the minimum water content needed for growth
 - 20%? – basic rule for decay fungi.
- Keep wood at 0% moisture?
 - Unrealistic!



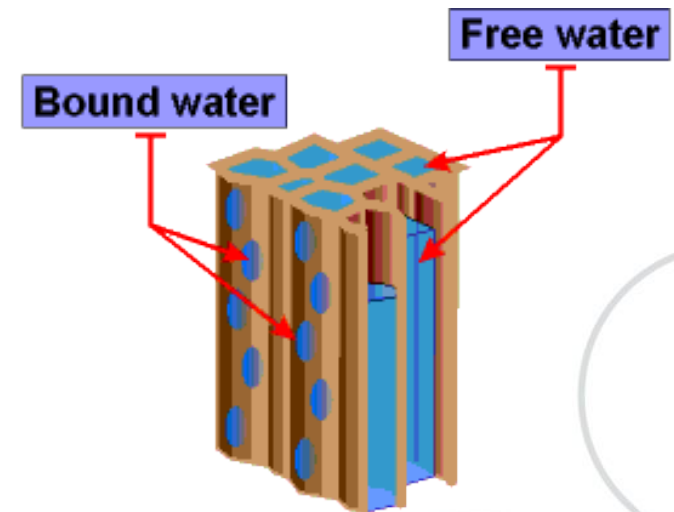
Sources of water

- Contact
 - Immersion
 - Capillary action
- Vapour sorption
 - Humidity
 - Condensation



How much water can a material hold?

- In wood we talk about bound and free water.
- Other materials may mention water holding capacity



**A MAGNIFIED
WOOD SECTION**



Material behaviour.

- Do all materials behave the same way under the same moisture environments
 - No!
- Different materials will have different sorption properties
- Different materials can have very different EMC's at the same humidity value



How can we test behaviour?

- Expose materials to differing moisture conditions and sources and test their behaviour.
- Contact
 - Immersion/ capillary action
- Sorption
 - Vapour sorption
 - Humidity chambers
 - Moisture permeability



Contact Hygroscopic property testing - immersion

- Water absorption - partial immersion: EN 15148
- Liquid transport co-efficient: EN15148
 - Bottom of sample (>5mm) immersed into water
 - Uptake of water determined by mass change over time



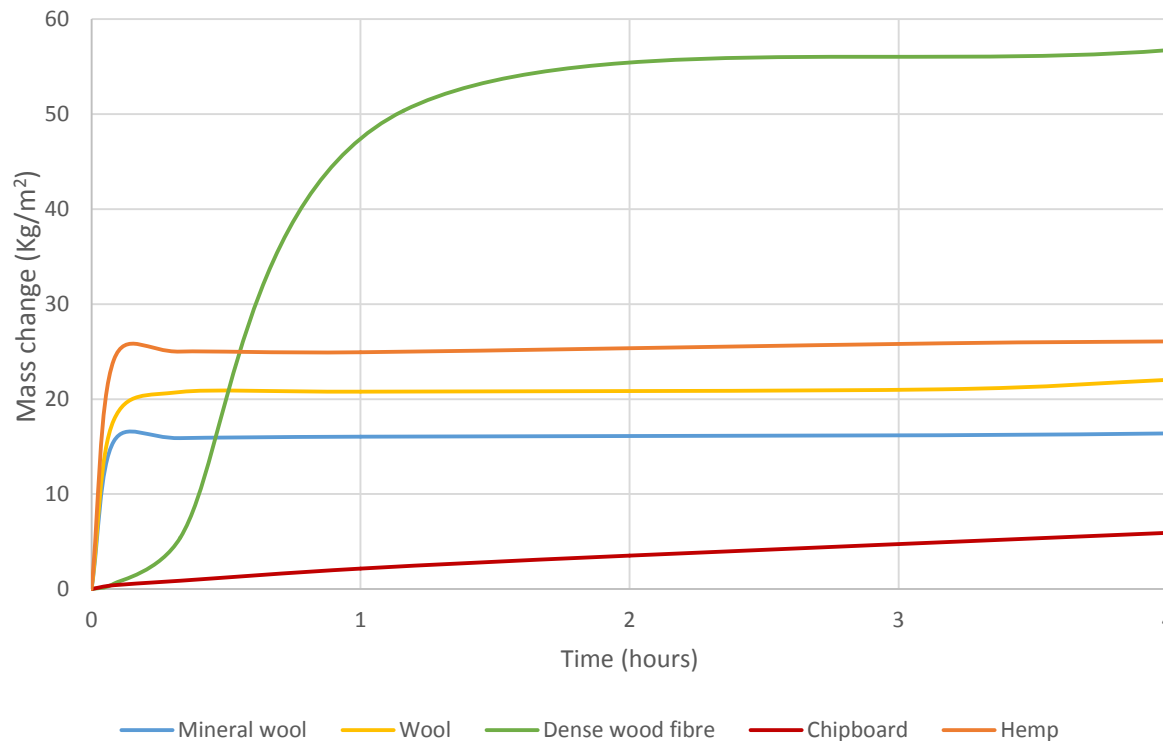
Immersion testing



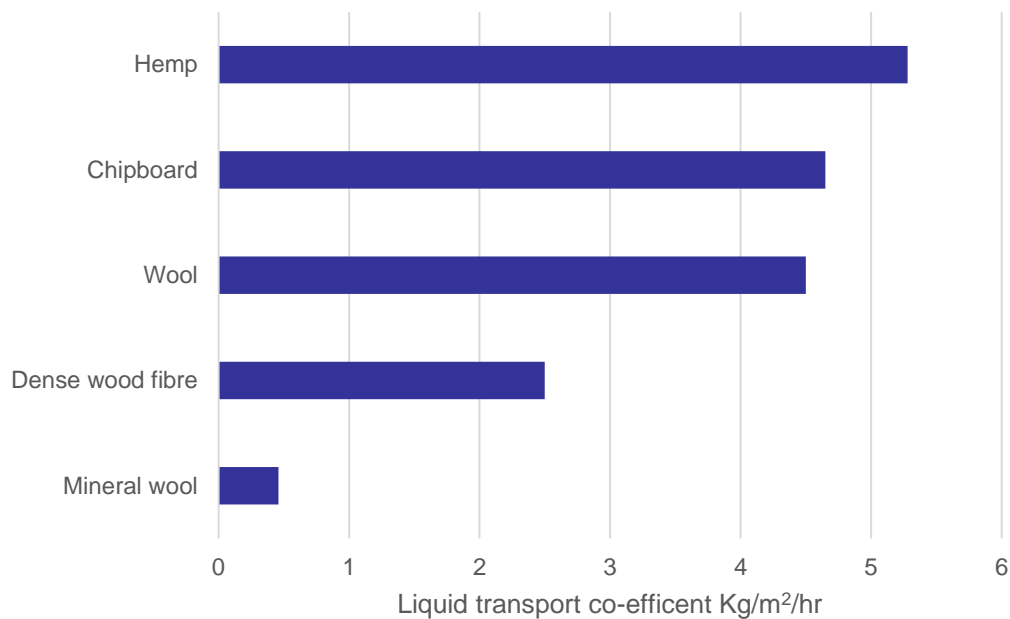
Test ends after 24hrs
or when the water
reaches the top



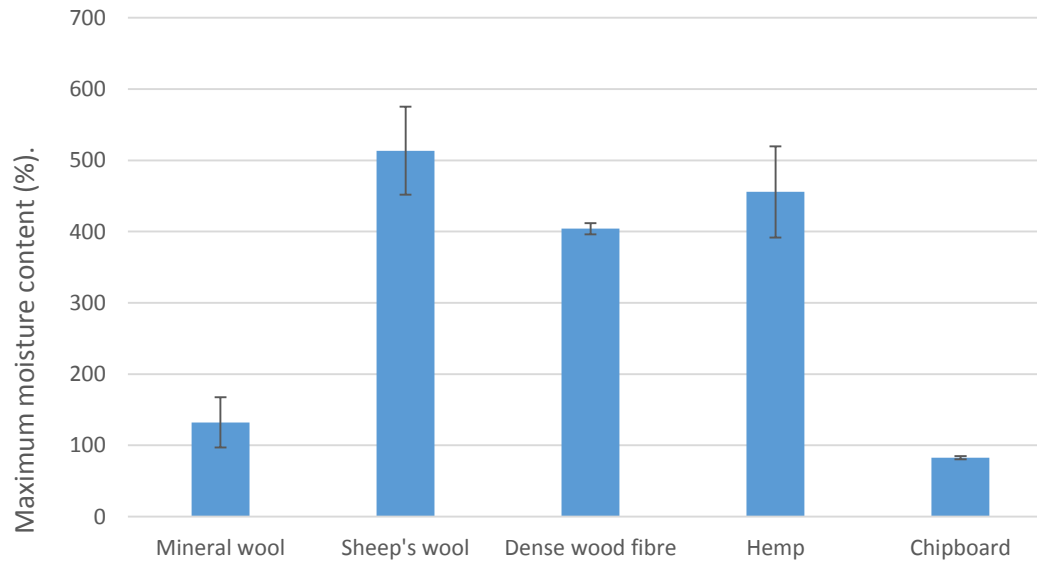
Water absorption by partial immersion



Liquid transport co-efficient



Maximum moisture content obtained



Implications

- How fast will a material absorb water
 - Short term weather events
 - Installation issues
 - Leaks
- Also how fast will it dry?



Fungal requirements

- How long does a material need to be at a high enough moisture content for fungi to grow?
 - Mould/stain fungi will be initial colonisers
 - Decay fungi subsequent attack
- Can established fungi survive dry periods?
 - Moisture cycling



Out of contact Sorption properties

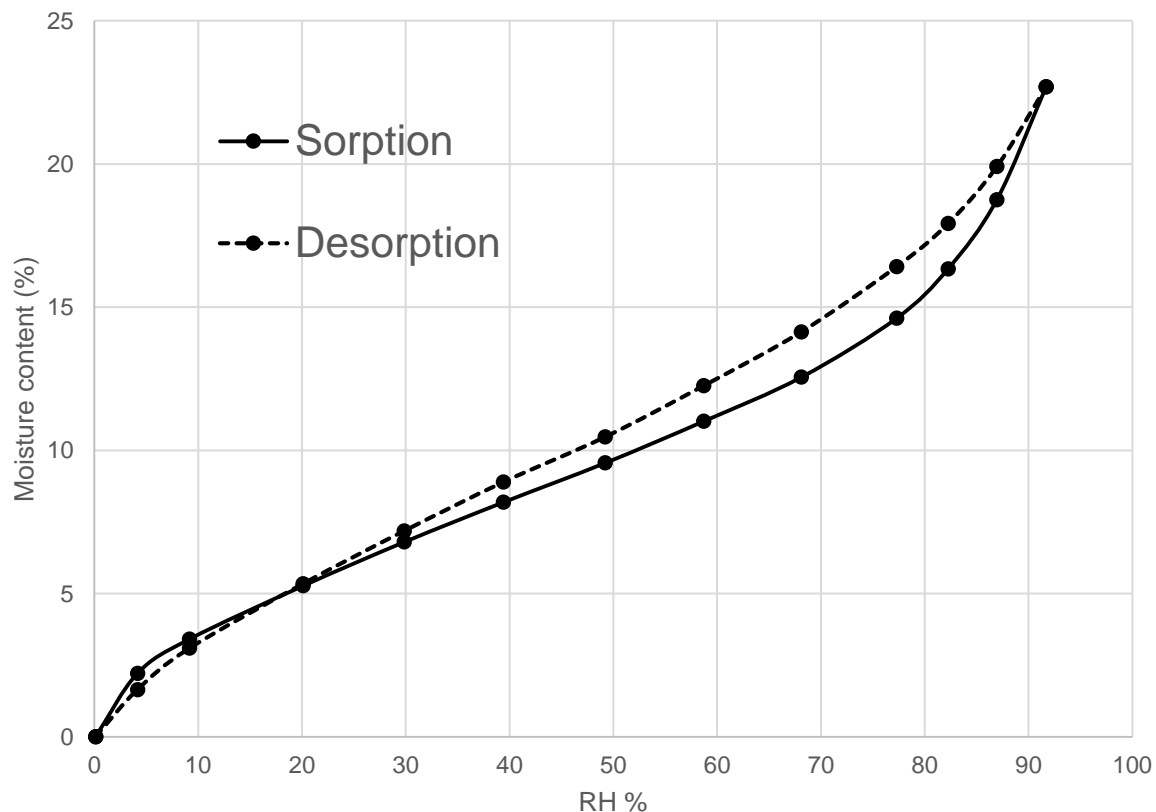


Dynamic Vapour sorption

- Small samples of material exposed to differing RH conditions
- Water absorption determined by mass change
- Isotherm developed from sorption/desorption curves.
- EMC at set RH values



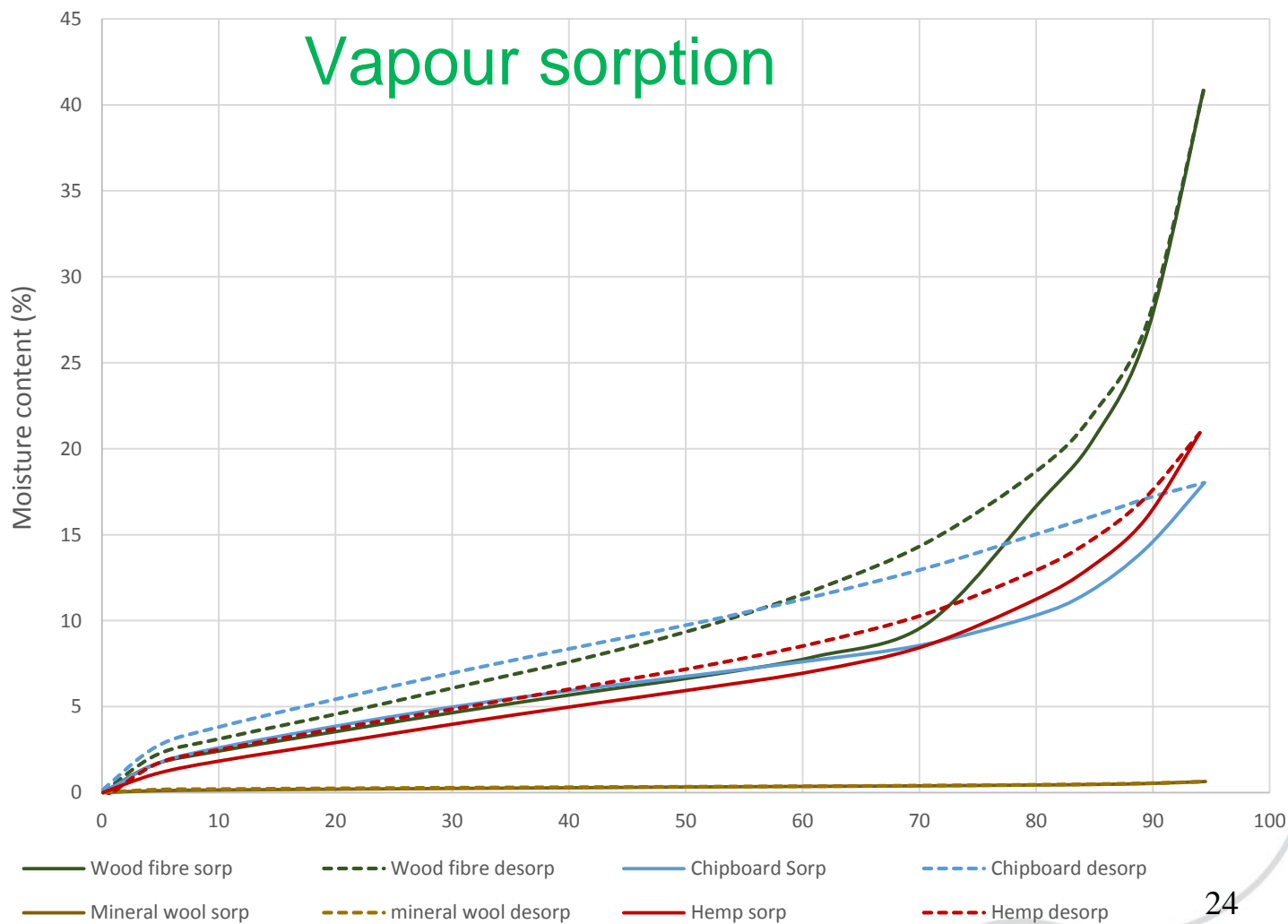
Typical Moisture isotherm



- Material Specific
- Change with temperature
- Change with cycling
- Hysteresis between wetting and drying



Vapour sorption



Dynamic vapour sorption – pros and cons

- Reliable
- Reproducible
- Quick
 - Few days up to maybe a week
- Small sample size
- May not account for product scale effects



Humidity chambers/salt tanks

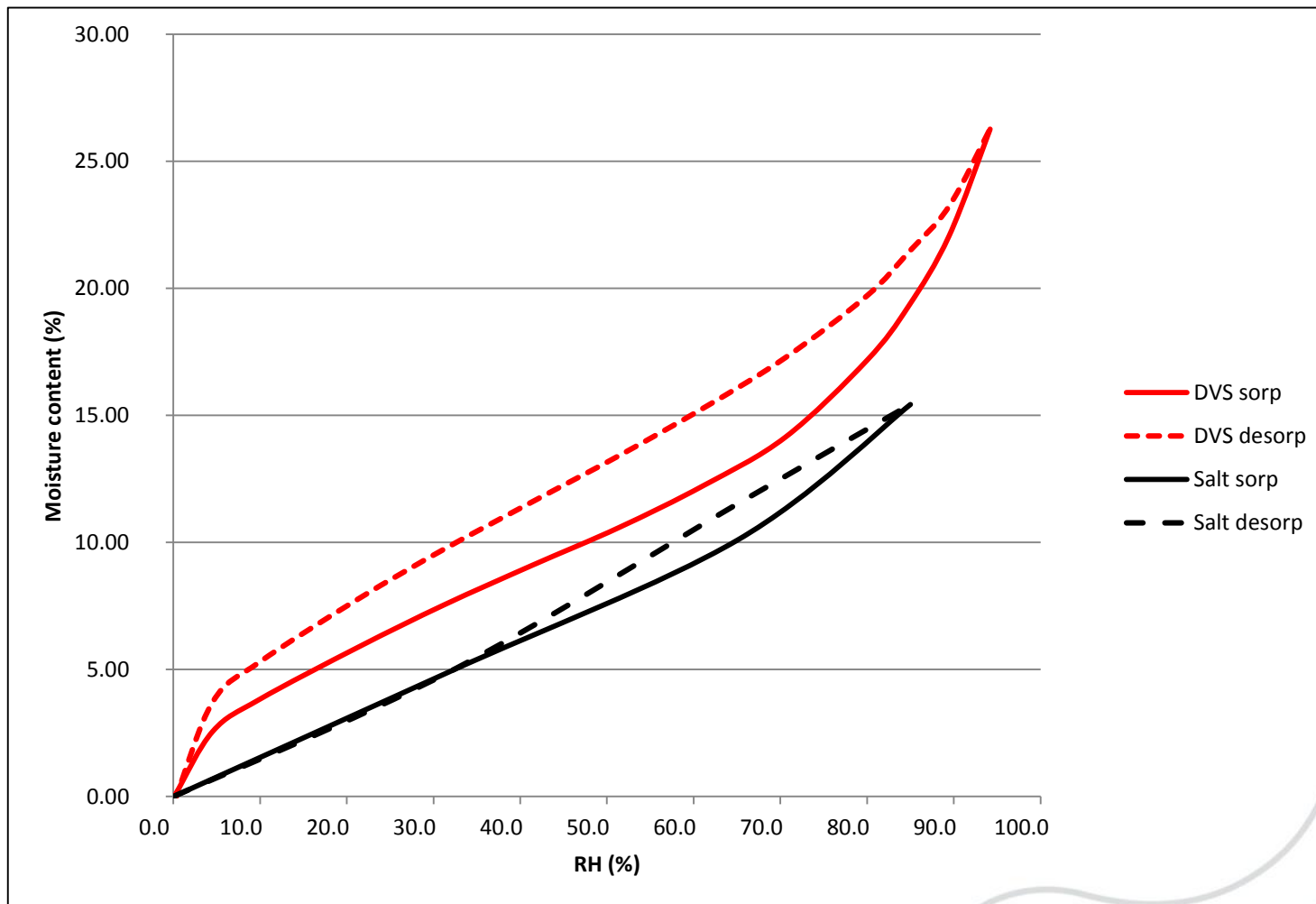
- Use saturated aqueous solutions of various salts to produce a defined humidity value within a chamber or tank.
- EMC at set RH values
- Produces isotherm curves



Salts used for humidity chambers

- Desiccants
 - Calcium chloride, - 0 %
- b) Aqueous solutions
 - Magnesium nitrate, 53 %
 - Potassium chloride, 85 %
 - Ammonium dihydrogen phosphate, 93 %





Salt tanks and DVS can give differing results!



Salt tanks – pros and cons

- Can take much larger sample sizes
 - Determine bulk effects of a product
- Takes much longer time period (several months!)
- Can give different results to DVS!

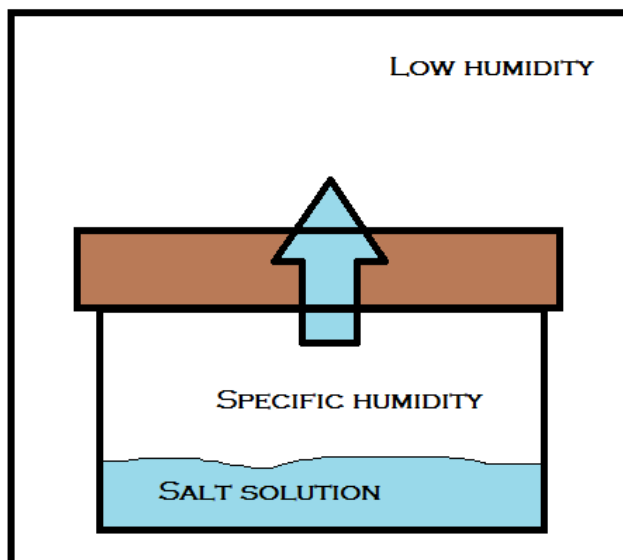
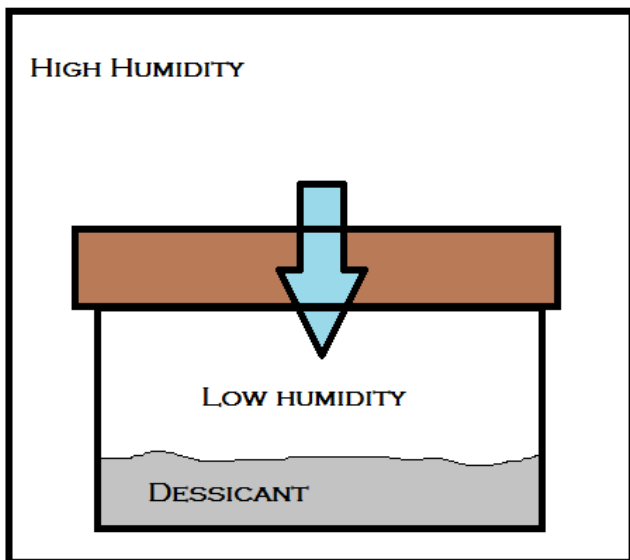


Water vapour permeability

- Its also important to know how water moves through a material and not just how much the material absorbs.
- Water vapour permeability
- May have effects on adjacent materials.



Water vapour permeability testing



Dry cup and wet cup method

Isothermal conditions

Determines the μ value



When thinking about moisture relationships

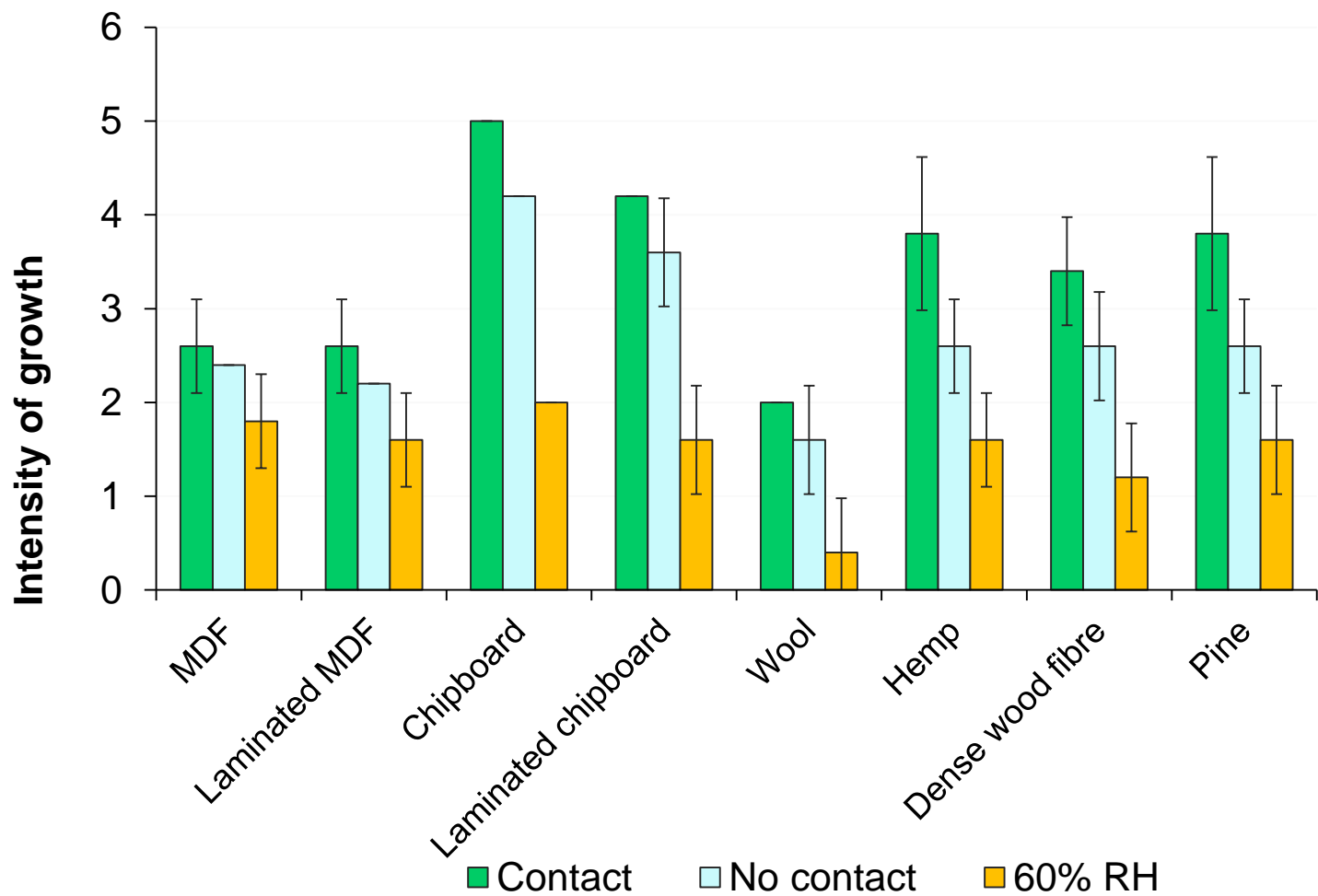
- We have to account for contact or vapour sorption
- Material or bulk (product) effects
- Permeability, transmission rates and actual amounts of water present!



So what does this mean for the fungi and material durability

- Still need methods to screen new materials
- Fast method developed by Bronia Stefanowski can be used to determine differing growth intensity of moulds under differing conditions.
 - BK Stefanowski, SF Curling, GA Ormondroyd (2017).
International Biodeterioration & Biodegradation 116, 124-132





Moisture condition effect on mould growth

Capillary

High humidity

Limiting humidity



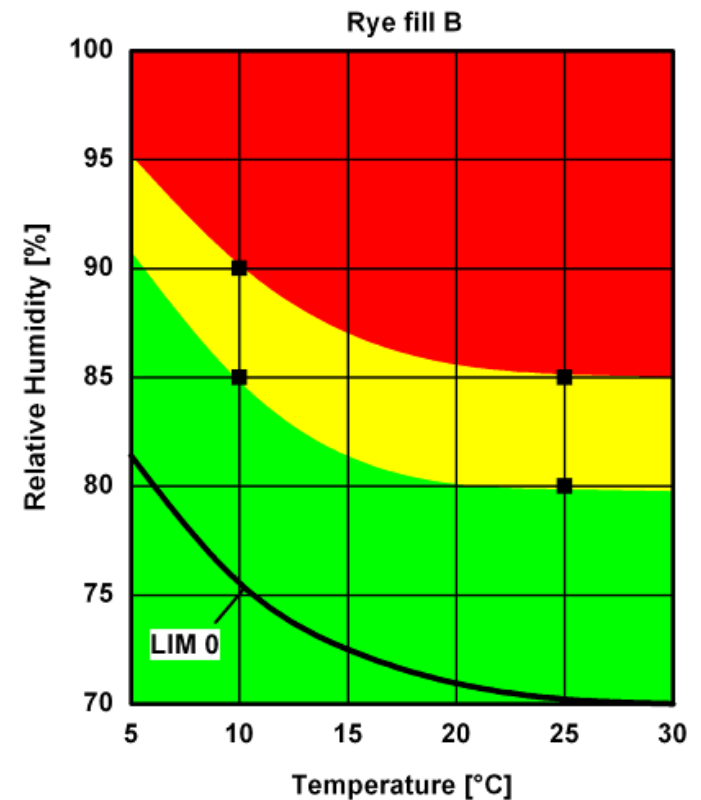
Can we put all this information together to determine risk?

- There are numerous models for the risk of mould growth under varying humidity risks.
- A recent one is the isopleth developed at Fraunhofer in Germany



Material specific risk

- Isopleth diagrams for mould fungi
- Colour coded risks
- Regions and values are material specific



What about the interaction of materials?

- Materials interact with each other
- If biobased materials are used in combination what are the implications for durability
- Modelling based on properties?
- Testing – lab, field or service?

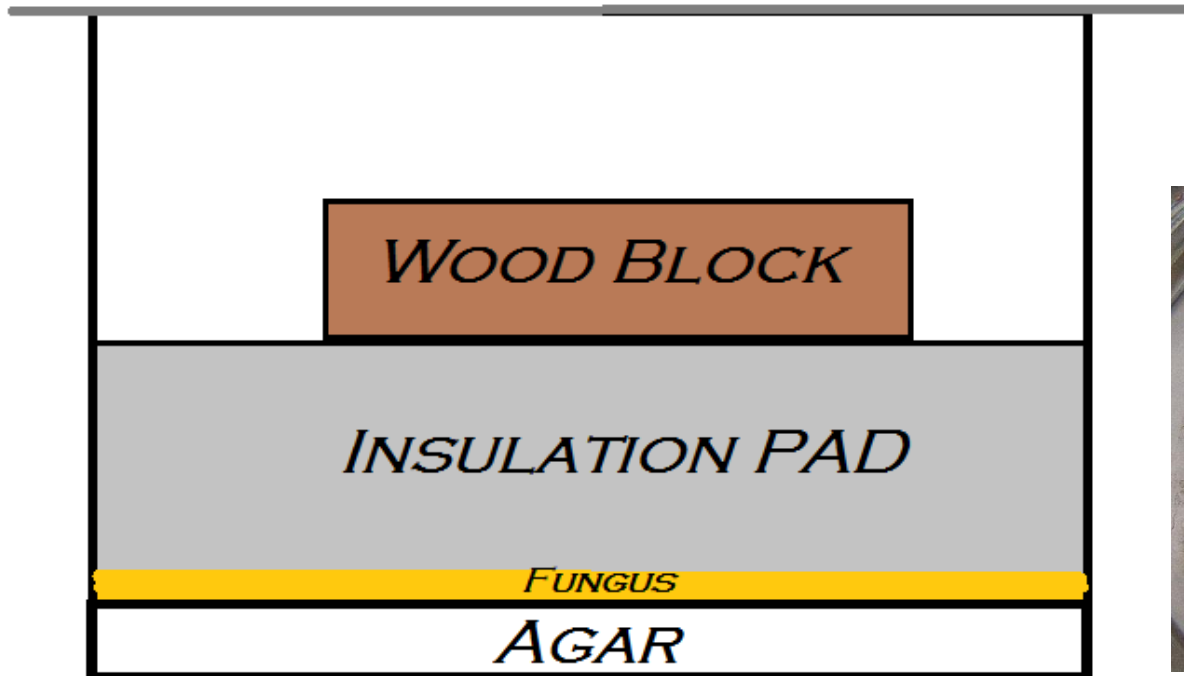


Testing durability of materials in combination

- Based on EN 113
- Uses pad of insulation between fungus and wood block
- *Used Coniophora puteana* (brown rot)



Test assembly



Results!



- Low levels of growth with wool pads



Mineral wool



- Growth on and decay of block evident



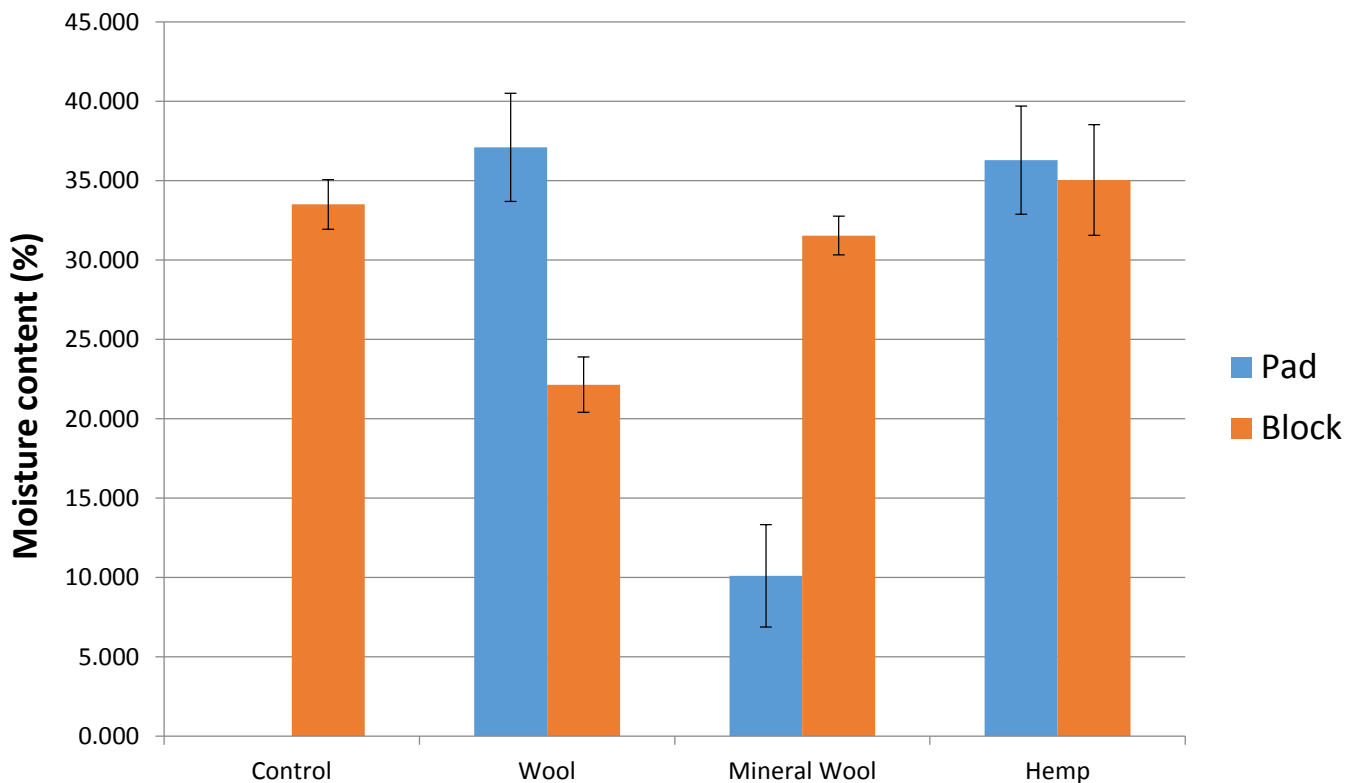
Hemp!



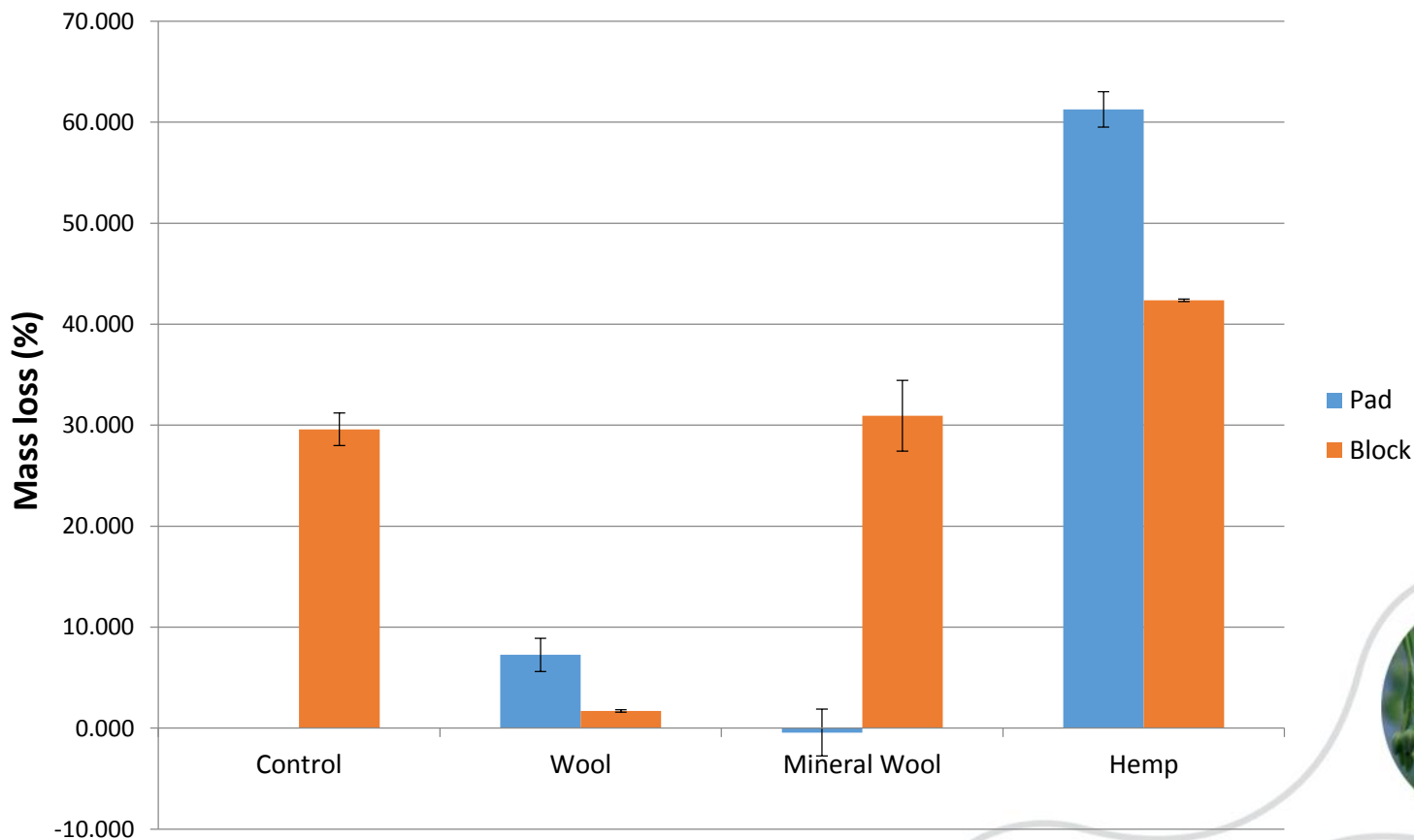
Considerable growth
and decay of both pad
and block!



Post exposure moisture content



Mass loss



In Summary

- We need data from testing for modelling
- We need to understand
 - How it was obtained
 - How does it apply to our chosen material
 - Is our material affected by interactions with other materials



Thank you for listening

- Any questions

