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The influence of water activity and air movement in preventing mould in historic materials

Introduction

Mould causes biodeterioration of historic materials (Ortiz-Miranda et al. 2017; Florian 1997) and is an issue in historic buildings, as well as in museums and storage spaces across the world. Furthermore, it is a health hazard for both heritage professionals and visitors that have contact with contaminated materials and objects (Heseltine and Rosen 2011).

This research aims to improve our understanding of conditions for mould growth by looking beyond temperature and relative humidity (RH) parameters used in building models, which evidence shows are insufficient by themselves.

Microbiology studies and the food industry focus on water activity (a_w), instead of RH, as one of the main parameter influencing mould development. This is considered the main factor to influence the germination of spores in contact with substrates and the consequent development of new mould colonies or mycelia that digest the substrate (Ayerst 1969; Pitt and Hocking 2009).
This parameter, characterised by the surface equilibrium relative humidity (ERH), may be poorly coupled to the room space conditions of temperature and RH due to several factors, such as the presence of microclimates, potentially more humid, and possibly the absence of air movement. For these reasons mould is often observed in locations where general environmental conditions suggest it would not grow.

As mould tends to develop in such microclimates, being humid basements an example (Maekawa and Toledo 2003), it is believed that air movement has the potential to be used as a preventive conservation measure in these spaces to reduce water activity on materials’ surfaces, and hopefully applicable to different types of buildings and climates.

There have been suggestions of environmental control in microclimates using air movement. At the National Trust it has been suggested an increase in ventilation around books in shelves to reduce RH by opening holes at the back of each shelf (Bendix and Pickwoad 2011). However, the mechanism through which mould development is reduced is not well known and it is not clear if its efficiency is due to a reduction in water activity of materials or in ambient RH, or even of both parameters.

This study assesses the impact of different air velocities on water activity, to understand how air movement can act as a preventive measure to control mould development in historic buildings.

Methodology

Changes in water activity were assessed over time in samples of wood (hardwood abachi, *Triplochiton scleroxylon*) and paper (handmade using pure cellulose unbleached wood fibres). Wood and paper were used as test materials to establish proof of principle and develop the methodology. They are facsimile to heritage materials, and commonly found in libraries in historic buildings and affected by mould.

The drying process was assessed using four air velocities: steady air, 0.01, 0.15 and 0.75 m/s. Samples were conditioned at 85% RH and 20 °C in an environmental chamber (Design Environmental Ltd Delta 335-40H - Temperature Humidity) and then transferred to a custom made environmental chamber (fig 1), where the experiment was conducted, at approx. 17% RH (controlled with a saturated solution of lithium chloride, ≥98%), and ambient temperature (approx. 20 °C).

The purpose of drying samples from 85 to 17% RH was to record the evolution of water activity over a range of humidities as wide as possible, which extends beyond usual conditions in historic properties.

Air velocities of 0.01 and 0.15 m/s were measured at the National Trust property, Blickling Hall, in book shelves with holes and behind bookshelves using heat plates, respectively. The higher velocity represents the air movement achieved by a household fan, usually used to dry objects after floods.

Water activity was measured using a water activity meter (HygroPalm-Rotronic), which measures the humidity of the volume of air in equilibrium with the sample. For the first 45 min readings were taken every 5 min. From 45 to 120 min, readings were taken every 15 min. Two more readings were taken at 240 and 360 min. Triplicate readings were taken for each time point.

Air movement was produced by an electric fan incorporated in the environmental chamber, and regulated using a barrier that blocks it to different extents, allowing control of the velocity over the samples. A hot wire anemometer (VelociCalc-TSI) was used to monitor the air velocity.

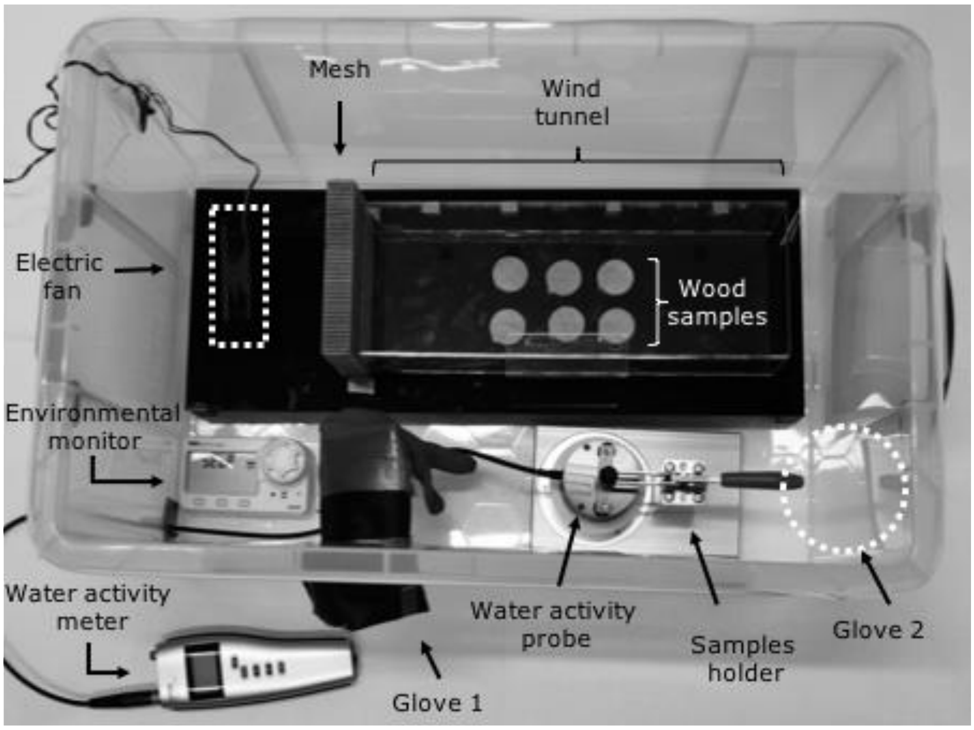

Fig 1 - Custom made environmental chamber and components, where experiment was conducted. Solution of saturated salts was placed under the black platform supporting the wind tunnel and electric fan. Glove 1 is attached to the side of the chamber, and glove 2 is attached to the top of the chamber.

Results and discussion

As observed in fig 2, for higher air velocities the rate of decrease of water activity increases. This demonstrates that potentially air movement could be explored as a measure to prevent mould development by reducing the water available for its development.

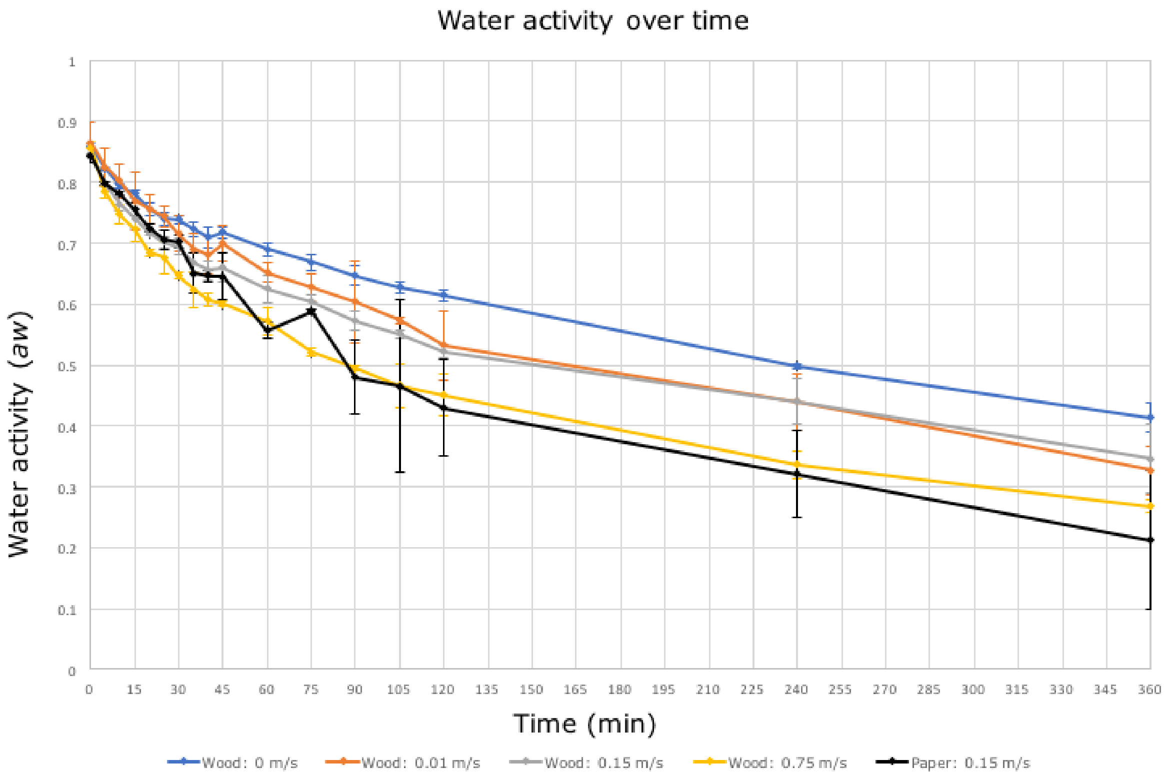

Fig 2 - Change of water activity over time, for the four air velocities tested. The error bars reflect the uncertainty in the determination of water activity in each time point and relates to differences in samples and in environmental conditions (mainly RH).

Furthermore, it can be observed that potentially the impact of air movement is dependent on the materials. A similar decrease in water activity in paper and wood samples was achieved, using a much lower air velocity for the paper samples (0.15 m/s) than for wood samples (0.75 m/s). And so, this discrepancy should be explored with materials that are more representative of heritage materials. Furthermore, it is important not only to assess the impact of air movement in different materials but also to consider aged materials, because chemical and physical properties change. Different characteristics in materials, such as porosity, will potentially have an impact on how water activity changes with air movement (Block 1953).

Thus, it is suggested that different air velocities will be necessary to cause a significant change in water activity depending on the materials at risk of mould biodeterioration.

Conclusions

As expected, higher air velocities were found to have a greater impact on reducing water activity for both materials tested. However, more importantly, the impact of air movement is suggested to be highly dependent on the type of materials. This could be crucial in designing preventive conservation strategies, defining efficient air velocities according to the materials present with the aim of achieving a significant change in water activity.

It is important to develop a more sustainable method reducing the energy used in controlling mould (De Silva and Henderson 2011; Cassar 2005). Thus, a minimum air velocity to efficiently reduce water activity should be determined, considering that ideal water activity levels vary for different mould species found in historic buildings (Florian 1997).

Future work

Further studies will explore different materials' response to air movement, assessing water activity changes, in the laboratory and in situ in historic buildings at the National Trust. These should focus on achieving a minimum air velocity that produces a significant impact on water activity.
Air velocities between 0.01 and 0.75 m/s should be explored. It is possible that an air velocity lower than 0.75 m/s could have a similar impact on change of water activity, and simultaneously be less invasive for an historic context. Areas with increased air velocity around objects have been shown to have a higher risk of particles deposition (Grau-Bové et al. 2016), and so lower air velocities could decrease this risk.

This research could also be used to develop a new predictive model based on the parameter of water activity or even adding water activity data to existing models used to predict mould development.

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