Water diffusion through hygroscopic cotton layers

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Résumé

As a typical biobased material, cotton is globally used for textiles. As a consequence, its hygrothermal behaviour is of vital significance since it can greatly affect the comfort or discomfort they procure due to the resulting wetness or heat loss along the skin. However, our current knowledge of water transfers through such materials is still limited (2). The major problem is the lack of information and proper description of water transport and phase changes inside the porous structure. Measurements remain challenging, in particular considering that the materials are not transparent and different states of water (free water, bound water, vapor) can coexist. The most difficult point is bound water, i.e., water absorbed inside the molecular structure of cell walls, which can hardly be detected with standard microscopy techniques, whereas it can represent a water mass of up to 30% of the dry mass of the material.
In this study, cotton fibre stacks are prepared at different porosities (0.2 to 0.9), to identify whether the water can transfer through the fibre network instead of the pores, the sample is filled with oil, only leaving one surface to diffuse (evaporation). Thanks to the NMR (nuclear magnetic resonance), we discover that bound water can diffuse through the fibre network up to the free surface of the sample. Correspondingly, the diffusion coefficient of bound water can be deduced from the water saturation vs time data with the help of a simple diffusion model properly taking into account the boundary conditions. This diffusion coefficient increases with the porosity due to the variation of compression, resulting in a different fiber orientations.
In addition to the bound water diffusion, we also give a direct determination of diffusion coefficients of vapor. To achieve this, a series of experiments of steady-state water transport were carried out through the cotton sample. Using the value of the diffusion coefficient of bound water determined as above, combining the boundary conditions under steady state, the fraction of transport due to vapor diffusion coefficient through the fibre stack were deduced.
These results allow a full description of water transfers (in the hygroscopic domain) through cotton clothes or insulation materials for construction.

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