Analytical solutions and Pore Network modeling of isothermal drying in porous media based on experimental studies

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ABSTRACT: We perform a series of drying experiments under environmental conditions with glass bead packings saturated by liquid hexane in Helle-Shaw glass cells to offer insight in the dynamics of the drying process. Our setup allows for monitoring the bulk liquid and gas phase distribution patterns, as well as the liquid films that form along the pore walls after the invasion of the bulk gas phase. We are thus able to classify the pore space into 3 distinct regions; a far-field region completely saturated by liquid hexane; a completely dry region, close to the side of the medium open to the ambient environment, that contains only hexane vapors; and finally an intermediate region, located between the first two, that is partially saturated by liquid hexane in the form of liquid films at the walls of the pores and by hexane vapors in the central part of the pore space.

The experiments reveal two distinct drying periods; an early constant drying rate period (CRP), that lasts as long as the film region is contact with the external surface of the medium; and a later falling rate period (FRP) that is related with the development of the dry region below the surface. The critical residual hexane saturation that marks the transition between these two regimes is found to be a function of the average bead size in our packings and the angle of the cells with respect to the flat surface, with larger beads and angles closer to the vertical position leading to shorter films and higher critical saturations.

Based on our experimental results we propose a pore network model that accounts for the major transport mechanisms within the porous medium coupled with mass transfer by diffusion through a mass boundary layer over the external surface of the medium. We show that in the limit of a gravity-stabilized drying front the medium can be treated as a 1D continuum where analytical solutions to the governing equations are derived. We are thus able to obtain results for the drying rates, the critical saturation and the extent of the film region with respect to the various dimensionless numbers that describe the process; the Bond number, a film-based Capillary number and a Sherwood number that accounts for mass transfer over the surface of the packing.