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Drying regimes in homogeneous porous medium from macro to nano-scale

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From MRI visualization of internal liquid distribution in time during convective (given air flux) drying of uniform bead packings with pore size from micro- to nano-meter, we show that, at first sight, the standard regimes of drying may be observed in any case: first a constant drying rate regime (CRP) associated with a homogeneous desaturation, followed by a falling rate period (FRP) associated with the growth of a dry region from the sample free surface, and during which the drying rate varies in accordance with vapor diffusion through the dry porous region. However several more original phenomena can be highlighted: 1) the duration of the CRP decreases when the pore size decreases (for a given air flux); 2) for pore size below say a few tenth of nanometers, despite an apparent homogeneous desaturation the drying rate continuously decreases, a phenomenon likely due to Kelvin effect; 3) at any time in the FRP the material still desaturates homogeneously in the wet region (below the dry region), which suggests the existence of continuous liquid flow towards the interface of higher evaporation, even for very low saturation or very small pore size. However, in the latter case, it appears that the corresponding net flow rate is almost independent of the pore size, an effect which cannot be described by a model based on a simple Darcy's law model with capillary effect as the driving force, which gives a scaling with the pore size. Instead it is likely that, paradoxically, even if this net flow is unidirectional and capillary driven, it is again governed by a series of diffused local capillary equilibrations throughout the sample, leading to a net liquid transport with a specific dynamics almost independent of the pore size.

References

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