Pore-scale study on convective drying of porous media by the lattice Boltzmann method

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In this work, a multi-component multiphase lattice Boltzmann method (LBM) is proposed and applied to convective drying of a dual-porosity porous medium at pore-scale. The pore-scale information can be directly resolved by the proposed numerical model. The drying dynamics are analyzed in detail in terms of pore-scale drying patterns, saturation profiles versus height, vapor concentration boundary layers, evaporation rate and periods as well as the behind mechanisms. From the numerical simulations, it is found the convective drying process of a dual-porosity porous medium follows the pattern that the evaporation front invades the large pores first and then penetrates the smaller pores. The evaporation rate undergoes a transition from a constant rate period (CRP, the first phase) to the falling rate period (FRP, the second phase). It is found that in the CRP, the evaporation rate increases with the inflow Reynolds number (Re), while in the FRP the evaporation curves almost collapse at different Re. The underlying mechanism is elucidated by introducing an effective Péclet number (Pe). It is shown that convection is dominant in the CRP, and diffusion in FRP, as evidenced by Pe>1 and Pe<1, respectively. Within the considered parameter range, we find a log-law correlation of the average evaporation rate in the CRP regime with the inflow Reynolds number. The present work provides new insights into the drying physics of porous media and its direct modeling at the pore scale.