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Effect of spatially correlated disorder on solute dispersion and mixing in partially saturated porous media

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The transport of solute particles is common in many natural and engineering processes, such as nutrition/contamination transport in subsurface systems or underground carbon dioxide sequestration. While most of the available investigations concentrate on single-phase scenarios, more often, multiple fluids coexist, denoted frequently as unsaturated conditions. Here, and by means of direct numerical simulation, the effect of spatially correlated disorder in pore size is examined for two-phase displacement in viscous fingering regime. Following the stabilisation of fluids interface (steady-state condition), the solute solution is introduced into the invading phase with lower viscosity. Simulation results indicate that the spatial disorder impacts solute migration through the invading phase saturation and tortuosity of velocity streamlines. A bimodal variation can be seen from the histogram of probability of pore-scale Peclet number with zones being mostly dominated by either advection or diffusion. In addition, there exists a transition region with an interplay between both advective and diffusive mechanisms. The creation of trapped regions focuses the flow into preferential pathways, resulting in a higher dispersion coefficient. This, on the other side, forms a concentration gradient transverse to the direction of flow, directing solute solution through diffusivity from preferential pathways to low-velocity zones.