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Plume dilution in three-dimensional porous media: experimental and modeling results

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Laboratory bench-scale experiments allow investigating the fundamental processes governing solute transport in porous media. In this work, we focus our attention on dilution and dilution enhancement of steady-state plumes in 3-D systems. We perform multi-tracer experiments at flow velocities relevant for groundwater (0.5-8 m/day) in fully three-dimensional homogeneous and heterogeneous porous media and compare the outcomes with the results of analogous experiments performed in more traditional quasi two-dimensional setups. We quantify dilution by the flux-related dilution index and apply numerical transport simulation to quantitatively interpret the experimental data. The results show that mixing enhancement determined by flow focusing in high-permeability inclusions is different in two-dimensional and three-dimensional domains. In fact, although dilution is larger in three-dimensional systems, the enhancement of transverse mixing due to flow focusing is less effective in fully three-dimensional flow-through systems than in quasi 2-D setups. The experimental and modeling results also highlight the pivotal importance of the parameterization of transverse hydrodynamic dispersion to determine the mixing enhancement factor. Furthermore, the compound-specific effects in the dilution of solute plumes are more pronounced in three-dimensional than in two-dimensional systems.