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Influence of flow dimensionality on compound-specific dilution in porous media: 2-D vs. 3-D flow-through experiments

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Dilution and mixing of solute plumes in groundwater strongly depend on transverse dispersion. Thus, the correct parameterization and upscaling of transverse dispersion is of critical importance for the quantitative description of solute transport problems. In this study we perform flow-through laboratory experiments to investigate the influence of flow dimensionality on transverse mixing. We present a high-resolution experimental setup to study solute transport and transverse mixing in three-dimensional porous media. We conduct multi-tracer experiments in the new 3-D setup and compare the results with the outcomes of analogous tracer experiments performed in a quasi 2-D system. We work under steady-state flow and transport conditions and consider a range of velocities relevant for groundwater flow (0.5-8 m/day). Transverse dispersion coefficients were determined from the high-resolution concentration profiles at the outlet of the flow-through chambers (7×7 ports in the 3-D setup and 7 ports in the quasi 2-D system), considering conservative tracers with significantly different aqueous diffusion coefficients: fluorescein and dissolved oxygen. To quantify mixing, we experimentally determine the flux-related dilution index using the flow rates and the concentrations measured at the inlet and outlet ports. The experimental results show a compound-specific behavior of the transverse dispersion coefficient and its non-linear dependence on the flow velocity in both 2-D and 3-D setups. Furthermore, our data demonstrate a dependence of transverse mixing on the dimensionality of the flow-through system, with substantially enhanced dilution and a more important compound-specific behavior in 3-D porous media.