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Investigation of mixing enhancement in porous media under helical flow conditions: 3-D bench-scale experiments

Gabriele Chiogna (1,2), Yu Ye (3), Olaf A. Cirpka (4), Peter Grathwohl (4), and Massimo Rolle (5)

(1) Technical University of Munich, Germany (gabriele.chiogna@tum.de), (2) University of Innsbruck, Austria, (3) Hohai University, Nanjing/China, (4) University of Tuebingen, Germany, (5) Technical University of Denmark,

Lateral mass exchange at the fringe of solute plumes is a fundamental process leading to plume dilution and reactive mixing. Mass transfer between the plume and ambient water can be considerably enhanced by helical flow occurring in three-dimensional heterogeneous anisotropic porous media [1-3]. We performed steady-state conservative tracer experiments in a fully three-dimensional flow-through chamber to investigate the effects of helical flow on plume spiraling and deformation, as well as on its dilution [4]. Helical flow was created by packing the porous medium in angled stripes of materials with different grain sizes to create blocks with macroscopically anisotropic hydraulic conductivity. The hydraulic conductivity of the blocks was varied in different experiments. Solute concentrations and flow rates were measured at high spatial resolution for samples collected at 49 outlet ports. This allowed us to quantify spreading and dilution of the solute plumes at the outlet cross section. Moreover, we collected direct evidence of plume spiraling and visual proof of helical flow by freezing and slicing the porous medium at different cross sections and observing the dye-tracer distribution. Model-based interpretation of the results allowed substantiating the effect of the helical flow field on plume dilution and on mixing-controlled reactive transport. The simulation results were evaluated using metrics of reactive mixing such as the critical dilution index and the length of continuously injected steady-state plumes.
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