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Effect of Anisotropy Structure on Plume Dilution and Reaction Enhancement in Helical Flows

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Abstract

Recent experimental and modeling works have shown how plume dilution and reactive mixing can be considerably enhanced by helical flows occurring in 3-dimensional anisotropic porous media. In this work, we propose a setup capable of generating locally helical flows due to the peculiar geometry of a heterogeneous inclusion [1]. A total of one hundred different realizations of the inclusion, were obtained by varying key parameters such as the spacing between alternated heterogeneous zones of coarse and fine materials, the permeability contrast between such matrices, the angle of the anisotropic structures with respect to the average flow velocity, and the magnitude of the seepage velocity. We performed both conservative and reactive transport simulations to investigate the effect of the inclusion's geometry and orientation on the patterns of twisted streamlines and on the overall dilution and reaction of solute plumes. The impact of helical flow on plume dilution and reactive mixing in the considered three-dimensional anisotropic setups was quantified using the flux-related dilution index [2] of both conservative and reactive tracers. This numerical experiment allowed us identifying optimal geometric configurations maximizing mixing and reactions, and yielding enhancement factors up to 15 times the outcomes of analogous simulations in homogeneous media. Interestingly, it was also possible to show that compound-specific diffusive/dispersive properties were still relevant despite the enhanced plume dilution in helical flows with important consequences for reactive mixing.

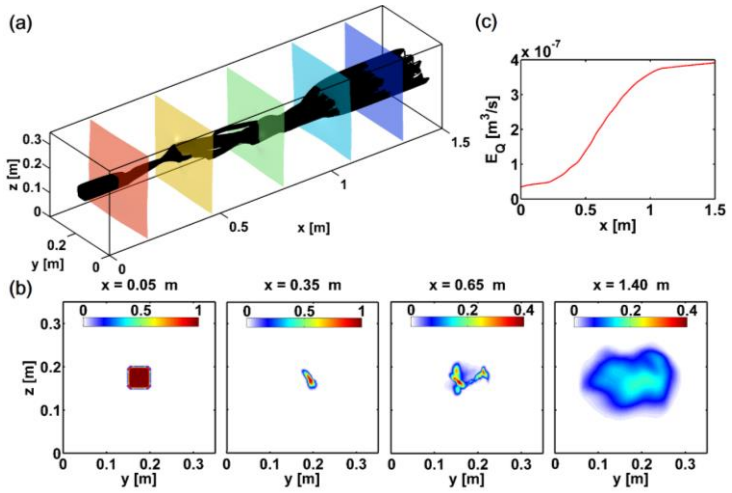

Figure 1: a) Streamlines traced from the central inlet show a twisting pattern; black lines: streamlines; colored surfaces: isosurfaces of hydraulic head; b) Concentration distribution at different cross-sections; c) Flux-related dilution index along the travel distance.

References

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[2] M. Rolle, C. Eberhardt, G. Chiogna, O.A. Cirpka and P. Grathwohl. Enhancement of dilution and transverse reactive mixing in porous media: Experiments and model-based interpretation. *Journal of Contaminant Hydrology*, 110, 130-142 (2009).