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Surface Induced Anomalous Transport of Nanoparticle in 3D Printed Structurally Heterogeneous Soils: coupling experiments and stochastic models

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Fate and transport of colloids and bio colloids in structurally heterogeneous porous media are known to exhibit anomalous behaviours such as non-Gaussian breakthrough curves. Classical approaches, like Colloid Filtration Theory, relies on spatial averaged quantities, neglecting flow topology heterogeneity brought about by both local pore scale surface irregularities and broad pores size distribution: two potential triggers for super diffusive effects and broad trapping time distributions. Recent theoretical work has tried to address these deficiencies by modeling deposition and flow variations as stochastic processes (Miele et al., Phys. Rev. Fluids 2019; Bordoloi et al., Nat. Commun. 2022). However, experimental evidence to demonstrate its validity for 3D geologic structures is still lacking. We thus design a novel experimental set-up to assess colloid fate transport under realistic structural heterogeneity with controlled laboratory conditions. Heterogeneous pore structures are first obtained from X-ray tomography of field samples and are subsequently 3D-printed at high resolution. Column transport experiments with gold (Au) nanoparticles are then conducted at different flow regimes, from which effluent concentration (at the macro scale) and colloid deposition (at the pore scale) are collected. These empirical data are complemented with pore network analysis that parametrizes the co-presence of preferential channels and stagnant cavities and, further, validates the stochastic model of interest. The findings shed light on the main drivers and structural hotspot for colloid filtration in realistic porous media.

Participation

In-Person

References

"Stochastic model for filtration by porous materials", Miele et al., Phys. Rev. Fluids 2019.

"Structure induced laminar vortices control anomalous dispersion in porous media", Bordoloi et al., Nat. Commun. 2022.

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