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Advances in colloid and biocolloid transport in porous media: particle size-dependent dispersivity and gravity effects

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Accurate prediction of colloid and biocolloid transport in porous media relies heavily on usage of suitable dispersion coefficients. The widespread procedure for dispersion coefficient determination consists of conducting conservative tracer experiments and subsequently fitting the collected breakthrough data with a selected advection-dispersion transport model. The fitted dispersion coefficient is assumed to characterize the porous medium and is often used thereafter to analyze experimental results obtained from the same porous medium with other solutes, colloids, and biocolloids. The classical advection-dispersion equation implies that Fick's first law of diffusion adequately describes the dispersion process, or that the dispersive flux is proportional to the concentration gradient. Therefore, the above-described procedure inherently assumes that the dispersive flux of all solutes, colloids and biocolloids under the same flow field conditions is exactly the same. Furthermore, the available mathematical models for colloid and biocoloid transport in porous media do not adequately account for gravity effects.

Here an extensive laboratory study was undertaken in order to assess whether the dispersivity, which traditionally has been considered to be a property of the porous medium, is dependent on colloid particle size, interstitial velocity and length scale. The breakthrough curves were successfully simulated with a mathematical model describing colloid and biocolloid transport in homogeneous, water saturated porous media. The results demonstrated that the dispersivity increases very slowly with increasing interstitial velocity, and increases with column length. Furthermore, contrary to earlier results, which were based either on just a few experimental observations or experimental conditions leading to low mass recoveries, dispersivity was positively correlated with colloid particle size.

Also, transport experiments were performed with biocolloids (bacteriophages: ΦX174, MS2) and colloids (clays: kaolinite KGa-1b, montmorillonite STx-1b) in packed columns placed in various orientations (horizontal, vertical, and diagonal) under both up-flow and down-flow modes. All experiments were conducted under electrostatically unfavorable conditions. The experimental data were fitted with a newly developed, analytical, one dimensional, colloid and biocolloid transport model, accounting for gravity effects. The results revealed that flow direction has a significant influence on particle deposition. The rate of particle deposition was shown to be greater for up-flow than for down-flow direction, suggesting that gravity was a significant driving force for biocolloid and colloid deposition.