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Why different transport behaviors emerge among identical nano- and micro-particles in porous media when repulsion exists

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A profound change in transport behaviors in porous media occurs for nano- and micro-particles (herein called colloids) in the presence versus absence of repulsion between colloids and collectors (porous media grains). This change is indicated by extended tailing of low colloid concentrations during elution, which is absent or present when repulsion is absent or present, respectively. It also manifests in the spatial distribution of retained colloids with distance from source (herein referred to as retention profiles), which are log-linear when repulsion is absent (favorable attachment conditions) and are either hyper-exponential or non-monotonic when repulsion is present (unfavorable attachment conditions). The deviation from log-linear retained profiles expected from classic colloid filtration theory can in some cases transform from hyperexponential to non-monotonic with increased ionic strength, and in some cases non-monontonic profiles may even shift down-gradient with increased elution. These deviations in the presence of repulsion all reflect increased colloid transport distances in the presence versus absence of repulsion that, given the variability of the deviations, are difficult to predict and further confound effective models for water resource protection. Understanding the source(s) of observed deviation from log-linearity is critical for predicting transport distances when repulsion exists, which is expected to be the predominant condition in environmental settings where both colloid and collector surfaces tend to be negatively charged. We herein demonstrate that the apparent distribution of "stickiness"among apparently identical individuals in a colloid population is a natural outcome of physicochemical influences on any colloid population in the presence of colloid-collector repulsion. We demonstrate this using recently-developed representation of the nanoscale charge heterogeneity responsible for colloid attachment in the presence of repulsion combined with trajectory modeling in impinging jet and Happel collectors. Having determined the pore scale origins of deviation from classic colloid filtration theory we upscale these influences to predict transport behaviors successfully at the continuum (column) scale. While field evidence indicates that nanoscale repulsion influences transport at the field scale, we are now in a position to predict and examine the influences of colloid-collector repulsion relative to important field scale effects such as alteration of surfaces via organic and inorganic sorption, precipitation and dissolution equilibria, physical heterogeneity and transient flow.

References

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