Conditioning preferential flow by using synthetic goethite aggregates

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Mass transport is significantly impacted by the nature of flow and, in particular, the occurrence of preferential flows. Most of the time, studies focus on observing preferential flow and its impact on mass transport either at the lab or the field scales. In the lab, real matrices are considered and embedded into columns, and mass transport is assessed for specific solutes and under controlled conditions (constant flow rate, saturation degree, etc...). However, very few studies use synthetic matrices and need to face matrix complexity in terms of both physics and chemistry. Such a complexity provides noise, uncertainty, and difficulty for the clear identification of mechanisms. This study made use of synthetized goethite nanoparticles as the reactant (sorption sites) combined to standardized sand to make a synthetic well-controlled porous medium. The goethite texture was changed during its fabrication to form two types of goethite-sand mixture: goethite-coated sand and goethite-aggregated sand. In the first case, goethite particles deposit at the surface of sand grains (forming a kind of coating), whereas goethite forms aggregates in the second case. The two types of columns were submitted to the injection of a tracer and two solutes: nalidixic acid (NA) and silicate. Our results show that flow remains mostly homogeneous, with the tracer following a straightforward ADE advection Dispersion Equation) process and no water fractionation into mobile and immobile water fractions. The minimal content of goethite (in the order of a few percent) does not change flow pathways. In contrast, the reactive transfer of NA and silicate is significantly impacted with less sorption, and much more solute spread in goethite-aggregated columns. NA and silicate cannot reach sites inside aggregates, reducing and slowing down their adsorption. In other words, changing the deposition mode of goethite nanoparticles on sand did not impact most of the flow and non-reactive transfer. It however greatly impacted reactive transfer. In addition, our results show that even if tracer experiments are performed for columns and attest of homogeneous flow, great care must be taken for reactive solutes. Tracers may not be the right tool to provide a clear picture of local hydraulic conditions at the vicinity of sorption sites, which are of utter importance for understanding reactive solute transfer.