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Colloid deposition and mobilization mechanisms in unsaturated porous media during steady and transient flow

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The transport of colloid-sized particles through vadose-zone soils has potentially important implications to water quality. Mineral colloids that are mobilized during infiltration events may carry sorptive contaminants through the vadose zone and into groundwater. Organic colloids, such as pathogenic bacteria and viruses, threaten human health when they are transmitted across the water table and into groundwater aquifers that are used as water-supply sources. The vadose-zone flux of colloids reflects, in part, the difference between colloid mobilization and deposition rates. Our research is aimed at improving predictive approaches for colloid transport through the vadose zone by elucidating the mechanisms that govern colloid mobilization and deposition within unsaturated porous media. This work relies on pore-scale observations of the transport of fluorescent microspheres through transparent flow cells packed with a thin layer of quartz sand. Results of these visualization experiments reveal that three mechanisms contributed to colloid deposition within unsaturated sand during steady flow. Colloids were held at air-water interfaces of insular air bubbles, strained within thin films of water that lined partially saturated pores, and stored within immobile-water zones that split from the primary flow channels. During steady flow, colloids were trapped irreversibly on the insular air bubbles and within thin films, but colloid storage within the immobile-water zones was partially reversible. Some of the colloids retained under steady flow were released during transient-flow periods characterized by temporal increases in flow rate and volumetric moisture content. Expansion of thin-water films during this flow-cell imbibition led to the release of formerly strained colloids. Mobilization by thin-film expansion did not dominate the overall release response, however. Comparatively more colloids were released when colloid-containing immobile-water zones were converted to mobile-water regions as water displaced air

upon flow-cell imbibition. The observations from these visualization experiments are being used to inform the development of a mechanistic model appropriate for predicting colloid mobilization, transport, and deposition during transient flow. Future work will focus on testing this mathematical model against data on the movement of mineral colloids through columns packed with partially saturated porous media.