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Identifying the role of flow rate and water content in colloid transport in unsaturated porous media

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Colloid transport in unsaturated soils and sediments is strongly affected by the presence of the air-water interface. The air-water interface is related to the water content, and as such, water content which plays a dominant role controlling colloid transport. The goal of our research is to elucidate the combined effects of water content and flow rates on colloid transport in unsaturated porous media. We conducted colloid transport experiments under different water contents and flow rates in sand columns containing silica sand with sizes ranging from 250 to 425 micrometers. Two different carboxylate-modified polystyrene colloids (26 and 200 nm diameter) were introduced to unsaturated columns under steady-state flow. The solution chemistry was chosen so that colloid transport occurred under unfavorable attachment conditions. By using a geocentrifuge, Flow flow rate and water content were varied independently in our experiments, which under normal conditions cannot be varied independently,is not possible were varied in our experiments independently by using a geocentrifuge. This unique experimental setup allowed us to run a series of colloid transport experiments at different water contents (effective saturation of 1.0, 0.6, 0.32, 0.19) but identical pore water velocity (10.6 cm/min). In general, decreasing water content led to increased colloid retention inside the columns. A portion of the retained colloids could be released by changing the solution chemistry, indicating that colloids had been retained in the secondary energy minimum. A DLVO analysis supports this assumption. We attribute unrecovered colloids in the outflow to the presence of flow stagnation zones. Overall the retention of the 26 nm colloids was stronger than the retention of the 220 nm colloids. Calculations of hydrodynamic forces suggest that the higher drag forces acting on the 220 nm colloids compared to the 26 nm colloids are responsible for the differences in retention.