Long-Term Colloid Mobilization and Colloid-Facilitated Transport of Radionuclides in a Semi-Arid Vadose Zone

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We have continued our work on microscopic characterizations and quantifications of colloid detachment by moving air-water interfaces. Experimental and theoretical results show that the advancing air-water interface was significantly more effective in detaching colloids from a glass surface than the receding interface. For hydrophilic colloids, the advancing interface movement generally exerts a stronger detachment force than the receding, except when the hysteresis of the colloid-air-water contact angle is small and that of the solid-air-water contact angle is large. To generalize these results, we expanded our work from spherical colloids to colloids of different shapes (barrels, ellipsoids, disks). Direct measurements of capillary forces acting on natural sediment particles from Hanford showed that particle shape (and surface roughness) is an important factor controlling the magnitude of capillary forces. We experimentally distinguished between the maximum capillary force and the snap-off force when the air-water interface detaches from the particle.

We continued the monitoring of colloid transport in the field lysimeters at the Hanford 300N Lysimeter Site. The facility consists of six lysimeters, each 7.6 m deep. Fiberglass wicks were installed at 1, 2, 4, and 7 ft below surface to collect vadose zone water. We applied Eu-hydroxycarbonate colloids to the lysimeters. Small amounts of Eu colloids were detected in the deepest wick sampler (7-feet depth) only 2.5 months after application and cumulative precipitation of only 20 mm. Large water infiltration, mimicking Chinook snowmelt events in late winter/early spring, caused peaks of Eu in the wick outflow. A main peak of Eu outflow was detected in 4- and 7-feet depth in December 2011 and January 2012 (2.5 years after colloid application). Our results indicate rapid transport of Eu colloids under natural precipitation and artificial irrigation, i.e., the leading edge of the Eu colloids moved at a velocity of at least 3 cm/day within the first two months after application. The main peak of Eu colloids, however, moved at a rate consistent with long-term recharge estimates.

To elucidate the combined effects of water content and flow rate on colloid transport in unsaturated porous media, we conducted colloid transport experiments under different water contents and flow rates. To independently control flow rates and water contents, we used the geocentrifuge at the Idaho National Laboratory. 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.