



Applicability of DLVO Approach to Predict Trends in Iron Oxide Colloid Mobility Under Various Physical And Chemical Soil Conditions

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In soil and groundwater, highly mobile iron oxide colloids can act as “shuttles” for transport of adsorbed contaminants such as heavy metals and radionuclides. Artificial iron oxide colloids are injected into polluted porous media to accelerate bacterial degradation of pollutants in the context of bioremediation purposes.

The mobility of iron oxide colloids is strongly affected by the hydraulic, physical and chemical conditions of the pore space, the solid particle surface properties, the fluid phase, and the colloids themselves. Most pioneering studies focused on iron oxide colloid transport and retention in simplified model systems. The aim of this study is to investigate iron oxide colloid mobility under more complex, soil-typical conditions that have as yet only been applied for model microspheres, i.e. functionalized latex colloids. Among these conditions is the pivotal impact of organic matter, either dissolved or adsorbed onto solid particles, modifying wettability properties. Of particular importance was to determine if effective chemical surface parameters derived from contact angle and zeta potential measurements can be used as a tool to predict general tendencies for iron oxide colloid mobility in porous media.

In column breakthrough experiments, goethite colloids (particle size: 200-900 nm) were percolated through quartz sand (grain size: 100-300 μm) at pH 5. The impact of a multitude of conditions on colloid mobility was determined: dissolved organic matter (DOM) concentration, ionic strength, flow velocity, flow interruption, partial saturation, and drying with subsequent re-wetting. The solid matrix consisted of either clean sand, organic matter-coated sand, goethite-coated sand, or sand hydrophobized with dichlorodimethylsilane. Additionally, contact angles and zeta potentials of the materials applied in the column experiments were measured. By means of these surface parameters, traditional DLVO interaction energies based on zeta potential as well as extended DLVO energies including Lewis acid-base parameters based on contact angle measurements were estimated.

The results elucidate that high mobility of goethite colloids was distinctly restricted to a narrow set of conditions: presence of DOM, sufficient flow velocity and constant flow, low ionic strength, full saturation as well as an uncoated and hydrophilic quartz sand matrix. Any deviation from these favorable transport conditions led from varying degrees of colloid retention up to complete immobilization. Results yielded by both traditional and extended DLVO interaction energy calculations demonstrated that increasing secondary minimum depth correlated well with higher colloid retention. Extended DLVO calculations revealed strong repulsive forces due to Lewis acid-base interactions at close distances that did not comply with experimental data. It is likely that Lewis acid-base interactions were limited due to surface roughness of the sand grains and colloids.

It can be concluded that the impact of various soil and hydraulic conditions on goethite colloid mobility is in principle assessable with column flow experiments. Moreover, with restrictions for the interpretation of close-distance interactions, DLVO interaction energies are capable of predicting general trends of goethite colloid mobility.