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Mobility of goethite colloids and Pb in goethite coated quartz sand: Effects of DOM preconditioning

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Both in colloidal form and as coatings on the soil matrix, iron oxides such as goethite have a high affinity for the adsorption of hazardous contaminants such as lead (Pb). Therefore, Pb can either be immobilized on iron oxides associated with the solid matrix, or can become highly mobile in soils and groundwater in case it is adsorbed on colloidal iron oxides. Furthermore, the mobility of iron oxide colloids and Pb can be significantly affected by the adsorption of soil organic matter. The aim of this study was to determine the transport and retention of goethite colloids and Pb in a simplified model system of goethite-coated sand (GCS) with clearly defined surface properties. A special focus was on the question how the conditioning of GCS with dissolved organic matter (DOM) percolation and the resulting changes in solid matrix surface properties affect the mobility of iron oxide colloids and Pb.
Synthesized goethite colloids with a mean particle size of 500 nm were applied, and GCS was produced from acid washed quartz and goethite. DOM was extracted from Fagus sylvatica litter material. Zeta potentials were calculated from electrophoretic mobility measurements. In shaken batch experiments, basic interactions between goethite, DOM, and Pb2+ were determined. Breakthrough experiments in columns filled with GCS were conducted in three pulses: (1) injection of a suspension containing organic matter coated goethite (OMCG) colloids and Pb2+, (2) injection of DOM in order to form OMCG surfaces on the GCS, and (3) a further injection of OMCG colloid-Pb2+ suspension.

Batch experiments showed a high affinity between goethite and DOM, and the Pb2+ adsorption was higher on OMCG surfaces than on pure goethite. In the flow column experiments, pulse 1 led to the almost complete immobilization of OMCG colloids in GCS, while Pb breakthrough amounted to 34% percent. In pulse 2, considerable amounts of DOM were retained in the columns, leading to the formation of OMCG surfaces on the GCS; the injection was conducted until the concentration in the effluent equaled the injected concentration. In pulse 3, OMCG colloids were highly mobile, resulting from the formation of OMCG coatings on the GCS during the prior pulse. In contrast, the transport of Pb2+ was only slightly affected, with a reduction to 23 %. In general, the batch and flow column results could be explained by zeta potentials, which showed that the positive potentials of pure goethite were reversed to negative via OM adsorption. Therefore, the DOM conditioning made the GCS less attractive for OMCG colloid retention and more attractive for Pb retention.

We conclude that DOM-induced changes on the zeta potential of GCS affected the mobility of OMCG colloids and Pb, with a more pronounced effect on colloid transport. To determine whether those transport principles can be transferred from our simplified model system to more complex systems, future experiments will be conducted with natural soil.

Keywords: Pb mobility; iron oxide colloids; DOM; mineral-organic associations