Water Chemistry Affects the Efficacy of Concentrated Suspensions of Iron Oxide Nanoparticles Used for Aquifer Reclamation

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Nanosized colloids of iron oxide enhance the subsurface microbial degradation of a wide range of organic contaminants and they are used as a technology to clean-up contaminated aquifers. These particles are synthesized with a coating of humic acids to increase their stability in aqueous suspension, a crucial property to ensure the subsurface mobility of concentrated slurries of this material. This study investigates particle properties, stability, and sedimentation in water as a function of chemistry and ionic composition. Goethite particles display high stability in different electrolyte solutions of NaCl and $MgCl_2$, consistent with a negative zeta potential of strong magnitude that implies an effective electrostatic stabilization. While goethite particles follow the predicted DLVO behavior in NaCl and show a high critical coagulation concentration, their aggregation is fast in the presence of calcium, even at very low ionic strengths (< 1 mM). This result is rationalized with the occurrence of bridging phenomena related to the interaction of calcium with adsorbed chains of humic acid, inducing fast flocculation and sedimentation of the suspensions. The dose of calcium, i.e., the concentration of calcium ions with respect to that of particles in the dispersion, is found to be the parameter governing these stabilization mechanisms. This result implies that more concentrated slurries may be more stable than dispersions of low particle concentration under certain conditions. Stability results correlate well with the extent of slurry transport within a column of saturated sand. These results suggest the possibility to design an effective remediation strategy for each specific site geochemical condition.

This work was partly funded by H2020 EU project ‘Reground’, G.A. n. 641768.