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Injection of polyelectrolytes enhances mobility of zero-valent iron nanoparticles in carbonate-rich porous media

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The application of nanoscale zero-valent iron (nZVI) for in situ groundwater remediation has received increased attention as a beneficial and novel remediation technique. A precondition for effective nZVI field applications is its delivery to the contaminated source zones. This has proved to be difficult due to the limited mobility of nZVI, which remains one major obstacle to widespread utilization of this remediation approach (O'CAROLL ET AL., 2012).

One important factor that controls mobility of nZVI is physical and chemical heterogeneity within the subsurface, such as mineralogical variations (KIM ET AL., 2012). In our previous study we showed that the nZVI transport in carbonate-rich porous media is significantly reduced compared to that in quartz porous media (LAUMANN ET AL., 2012). This is caused by favorable nZVI deposition onto carbonate sand and is attributed to the less negative surface charge of carbonate compared to that of quartz sand under the range of water chemical conditions typically encountered in aquifers. New strategies are therefore required to improve nZVI mobility in carbonate-rich porous media. One approach can be the injection of polyelectrolytes in the subsurface, which are expected to adsorb onto aquifer grains and provide greater repulsion between nZVI and the porous media.

In this study the effect of co-injected polyelectrolytes on the transport of polyacrylic acid (PAA) coated nZVI in two model porous media, quartz and carbonate sands was evaluated. Column experiments were carried out aiming to evaluate mobility of PAA-nZVI co-injected with four polyelectrolytes, including natural organic matter (NOM), humic acid, carboxymethyl cellulose (CMC), and lignin sulfonate.

The results demonstrated that the co-injection of the chosen polyelectrolytes does not influence mobility of PAA-nZVI in quartz sand; the breakthrough with co-injected polyelectrolytes was similar to that of the pure PAA-nZVI dispersion. This observation can be explained by the strong negative surface charge of the quartz sand, which was apparently not changed in the presence of polyelectrolytes. Conversely, the co-injected polyelectrolytes affected the breakthrough in carbonate sand, increasing nZVI mobility for approximately 15%. This can be explained by the attachment of the polyelectrolytes to the less negatively charged carbonate sand, which then promoted the PAA-nZVI mobility.

Even though there are structural differences among the polyelectrolytes applied in this study, our results showed no significant variations in the PAA-nZVI mobility when these polyelectrolytes are present at concentration of 50 mg L-1. Lignin sulfonate was furthermore selected to investigate the effect of different polyelectrolyte concentrations (0, 10, 25, 50, 250, and 500 mg L-1) on the PAA-nZVI mobility.

The results showed that higher lignin sulfonate concentrations (250 and 500 mg L-1) do not affect the transport of PAA-nZVI in quartz sand. In carbonate sand, on contrary, increasing mobility due to co-injected lignin sulfonate was observed at concentrations above 25 mg L-1, having the highest value with 500 mg L-1 co-injected with the PAA-nZVI dispersion.

Overall, the results demonstrated that lignin sulfonate adsorption onto the carbonate sand reduce PAA-nZVI deposition onto aquifer grains and promote its mobility, the effect which is more pronounced at higher polyelectrolyte concentrations co-injected with the PAA-nZVI dispersion.

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Literature

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