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Enhancing nZVI mobility in porous media using humate

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The limited transport of nanoscale zero-valent iron (nZVI) particles in porous media is a major drawback for its use in groundwater remediation. Among other factors, transport of nZVI particles might be negatively affected by mineralogical and physical heterogeneities of the aquifer matrix. Carbonate minerals and iron oxides, for instance, provide positively charged patches which would further increase particle attachment to the sand grains.
This study does assess the potential of sodium humate, a salt of humic acids, to enhance the mobility of nZVI particles. Humate is a non-toxic, inexpensive material extracted from natural oxidized lignite and obtained in commercial grade, which makes it advantageous for field applications. Humate is expected to shield the positively charged patches of the sand grains and consequently enhance nZVI mobility in porous media. In this study the humate was injected into an aquifer prior to injection of the nZVI particles. The potential of humate for enhancing the mobility of nZVI particles was tested in an array of columns packed with heterogeneous natural porous media of different mineralogical composition and sediment texture.
The results demonstrated that without pre-injection of humates only limited mobility of nZVI particles can be obtained in all tested porous media. After the pre-injection of low concentration of humate (10 mg/L) the mobility of nZVI particles (1 g/L) was enhanced in all tested porous media. The magnitude of this enhancement was depended on the properties of the porous media. The largest improvement of nZVI mobility was observed for homogeneous quartz. This material had also the highest porosity ($\sim$ 40%), good sorting, and therefore a higher permeability compared to the other porous media tested. It is assumed that the higher permeability of this porous medium allowed an optimal distribution of humate, resulting in an approximately 6-fold enhancement of nZVI mobility. In carbonate-rich porous medium with a lower permeability a 1.5-fold enhancement of the nZVI mobility was observed. Enhanced nZVI mobility (up to 1.2-folds) was also observed for the porous media containing high quartz content and lower porosity. This might be attributed to the iron oxides minerals present in this porous medium.
The results of this study showed that the pre-injection of humate can enhance the mobility of nZVI in various natural porous media. Enhancement of nZVI mobility was more pronounced in porous media with the highest permeability and porous media with higher carbonate or iron oxide content. The humates shield the positively charged patches and therefore make the overall charge of the porous media more negatively charged. Consequently, the mobility of the negatively charged nZVI particles due to electrosteric and electrostatic repulsion was promoted. Future work will focus on understanding the mechanisms leading to the different attachment of humates onto the porous media. This research receives funding from the European Union's Seventh Framework Programme FP7/2007-2013 under grant agreement n°309517.