Electrokinetic delivery of reagents for groundwater remediation

Doctoral Dissertation
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Summary

The promising results obtain from laboratory and pilot-scale application of electrokinetic transport to the delivery of amendments for groundwater remediation are leading to an increasing interest for the techniques as a valid alternative to hydraulic injection in porous media. The different transport mechanism for EK leads to a better mixing with the pore solution, and thus the contaminant, and allow to overcome the limitation posed by low-permeability areas, simultaneously addressing the issue of back diffusion from the latter. A deeper understanding of electrokinetic phenomena in complex geometries (higher than 1D) and scenarios (heterogenous porous medium) is therefore pivotal for its efficient and effective implementation in full-scale implementations. The present work aims to investigate some of the complex mechanism involved in the EK transport of solutes, increasing the current knowledge-base and providing tools and information for a more efficient use of EK in groundwater remediation application.

Two-dimensional experiments were performed to investigate the influence of charge interactions phenomena in homogenous permeable porous media. The use of a full 2D geometry allowed to enable multidimensional transport components and investigating their mechanism and impact on extent on mixing and reaction kinetics toward a model pollutant. It was possible to show that the pore solution composition controls the delivery, spatial distribution and mixing of the injected amendments; reactivity experiments allowed to elucidate the impact on the reaction rates and amendment efficiency. Important implications are drawn, of both scientific and practical relevance; the gained knowledge on the mechanism and effect of charge interactions opens to the possibility of employing such effect to control and maximize the delivery efficiency. The process-based mathematical model developed will provide an important tool to support the design of EK implementation to improve the distribution of reactants and nutrients.

Experimental tests on the delivery and reactivity of amendments in low permeability inclusion were performed in 1D geometry, to determine the impact of charge interactions, determine the optimal parameter for the delivery and assess the ability of the reactants to remove a model pollutant. The use of a buffer in the electrode chamber allowed to prevent the plume stalling commonly associated to EK delivery in low permeability porous medium; it was also possible to determine an influence of the buffer ionic concentration on the migration velocity without any

modification in the potential gradient applied. Lastly, electrokinetic transport was applied to the delivery of amendments in clay inclusions in a 2D geometry for which hydraulic delivery proved unable to penetrate the low-permeability inclusion as expected. For electrokinetic transport, the results of the previous experiments played a fundamental role in defining the optimal conditions for the delivery. Exploiting the multidimensional effect arising from charge interactions it was possible to reduce the plume displacement and maximize its penetration in the clay layer, whereas a non-optimized protocol showed significantly lower efficiency (although still higher than advection-dispersion). The results obtained are very promising in the application of EK for the remediation of groundwater in heterogeneous aquifers, as it would be possible to improve the decontamination of low-permeability area reducing the secondary contamination arising from back diffusion.