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Tuning nanoparticle injection and immobilization for an effective groundwater remediation

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Nanoremediation, consisting in the subsurface injection of a reactive colloidal suspension for the in-situ treatment of contaminated aquifers, is an innovative and effective remediation technology. Despite the evidence of its effectiveness obtained in the last years, still some relevant challenges are to be faced and solved for a wider application. Among these, a relevat one is the effective delivery and immobilization and the appropriate dosing of the nanoparticles into the subsoil. These are necessary for the correct emplacement of the in situ reactive zone and to minimize the overall cost of the reclamation and the potential secondary risks associated to the uncontrolled migration of the injected particles.

In this study, a model assisted strategy, NanoTune, is developed to control the distribution of colloids in porous media. The proposed approach consists in the sequential injection of a stable suspension of reactive nanoparticles and of a destabilizing agent with the aim of creating a reactive zone within a targeted portion of the contaminated aquifer. The controlled and irreversible deposition of the particles is achieved by inducing the mixing of the two fluids in the desired portion of the aquifer.

This approach is here exemplified by the delivery of humic acid-stabilized iron oxide nanoparticles (FeOx), an innovative reagent developed in the framework of the H2020 project Reground (for the in situ immobilization of heavy metals. Divalent cations, which are known to cause rapid aggregation of the suspension because of their strong interaction with the humic acid coating, are used as destabilizing agents. The injection strategy is here applied in 1D columns to create a reactive zone for heavy metal removal in the central region of the sandy bed. The controlled deposition of nanoparticles at the desired location is achieved by tuned sequential injection of pulses of a particle suspension, a solution of divalent cations (used as destabilizing agent), and water (used to separate the two interacting fluids). The two fronts, which advance at different rates, overlap at the target location, where the particles deposit and accumulate irreversibly, creating a reactive zone. The software MNMs (www.polito.it/groundwater/software) was used here to assess the correct sequence and duration of the injection of the different solutions in the 1D medium.

The strategy, developed in 1D systems using FeOx, can be generalized and extended for application to any other colloidal suspensions, provided that a suitable destabilizing agent is first identified, and was tested at larger scales (2D geometries). Examples are briefly presented. The approach proposed in this work represents an important step forward in the field of nanoremediation, since for the first time it was possible to achieve control on the short- and long-term distribution of engineered particles upon injection.

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