Induced Polarization imaging of nano- and micro-scale particle injections for in-situ groundwater remediation

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The injection of nano- and micro-scale particles has emerged as a promising in-situ remediation technology for the treatment of contaminated groundwater, particularly for areas difficult to access by other remediation techniques. The performance of nanoparticle injections, as a foremost step within this technology, is usually assessed through the geochemical analysis of soil and groundwater samples. This approach is not well suited for a real-time monitoring, and often suffers from a poor spatio-temporal resolution. To overcome these limitations we propose here the application of Induced Polarization (IP) imaging as a diagnostic tool to evaluate the fate and transport of the injected particles. Our results demonstrate that the analysis of spatial and temporal changes in the electrical images allows tracking the propagation of the injected suspension and detection of the induced geochemical changes in the subsurface in real time. IP monitoring results presented here refer to two different experiments conducted at the field-scale: (i) during the injection of nanoGoethite particles (NGP) used for the degradation of a BTEX plume (i.e., benzene, toluene, ethylbenzene, and xylene); and (ii) during the injection of microscale zero-valent iron (mZVI) to enhance chemical transformation of chlorinated aliphatic hydrocarbons (CAHs). Preinjection imaging results revealed highelectrical conductivities for data collected in both investigations. Such responses can be explained by the release of metabolic by-products accompanying the stimulation of microbial activity due to the presence of hydrocarbons in the subsurface. Moreover, background images of the induced polarization (IP) reveal contrasting signatures for the different pollutants. Such footprints can be explained by variations in the pore-space geometry imposed by the distinctive properties of the pollutants. Post-injection images revealed a significant change (> 50%) in the electrical conductivity and induced polarization response. Temporal changes in the electrical images are consistent with variations in particles concentration observed in groundwater and soil samples, as well as geochemical parameters such as pH and oxidation-reduction potential. Moreover, large variations in the electrical parameters, close to the surface, reveal the formation of preferential flowpaths and the deviation of the particles from the target area. Our results demonstrate the applicability of IP imaging for the real time monitoring of nano- and micro-scale particle injection.