

Electrical imaging of subsurface nanoparticle propagation for in-situ groundwater remediation

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Application of nanoparticles has emerged as a promising in situ remediation technology for the remediation 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 and only provides information from areas close to the sampling points. To overcome these limitations we propose the application of non-invasive Induced Polarization (IP) imaging, a geophysical method that provides information on the electrical properties of the subsurface. The analysis of temporal changes in the electrical images allows tracking the propagation of the injected nanoparticle suspension and detection of the induced bio-geochemical changes in the subsurface. Here, we present IP monitoring results for data collected during the injection of Nano-Goethite particles (NGP) used for simulation of biodegradation of a BTEX plume (i.e. benzene, toluene, ethylbenzene, and xylene) at the Spolchemie II site, CZ. Frequency-domain IP measurements were collected parallel to the groundwater flow direction and centred on the NGP injection point. Pre-injection imaging results revealed high electrical conductivities ($> 10 \text{ S/m}$) and negligible polarization effects in the BTEX-contaminated part of the saturated zone (below 5 m depth). The apparently contradictory observation – BTEX compounds are poor electrical conductors – can be explained by the release of carbonic acids (a metabolic by-product of the biodegradation of hydrocarbons), which leads to an increase of the electrical conductivity. Post-injection images revealed a significant decrease ($> 50\%$) of the electrical conductivity, with even larger changes in the proximity of the injection points, most likely due to the relatively high resistivity of the NGP suspension. This is in line with geochemical data from both the injected NGP suspension and the groundwater samples. Furthermore, temporal changes in the IP images are consistent with variations in total iron concentration in groundwater (a proxy for the NGP concentration) as well as in situ groundwater parameters, such as pH and oxidation-reduction potential. Our results demonstrate the applicability of IP imaging for the real-time monitoring of nanoparticle injection, as well as of the accompanying geochemical changes.

Part of this research is funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 309517.