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Delineation of BTEX contamination plume with SIP imaging

Adrian Flores Orozco (1), Christoph Oberdörster (1), Ludwig Zschornack (2), Carsten Leven (3), Holger Weiss (2), and Andreas Kemna (1)

(1) Department of Geodynamics and Geophysics, University of Bonn, Germany , (2) Helmholtz Centre for Environmental Research (UFZ), Leipzig, Germany, (3) Centre for Applied Geoscience, University of Tübingen, Germany

In the framework of the EU FP7 project ModelPROBE, spectral induced polarization (SIP) measurements at a wide frequency range were conducted in Zeitz (NE Germany). The study area is located on the grounds of a former hydrogenation plant, where high concentrations of hydrocarbon contaminants are present. In the source area total concentrations of BTEX contaminants partly exceed 1000 mg/l. Previous studies at the laboratory scale have demonstrated a characteristic SIP response for different organic contaminants; however, there is no study conducted at the field scale for a wide frequency range. The aim of the study was to investigate the potential of SIP imaging for the characterization of different contaminants, their concentrations and degradation. Based on the project approach, the ultimate goal is to develop a minimally invasive methodology to assess the fate and transport of contaminants in-situ with high spatio-temporal resolution, useful for the optimization of remediation techniques. SIP measurements were performed in a profile with electrodes placed on the surface in the frequency range from 60 mHz to 1 kHz. Data errors were evaluated in terms of discrepancy between normal and reciprocal measurements in order to avoid over- or under-fitting in the imaging. In a later project stage, a trench was excavated along the location of the profile in order to remove pipes, foundations and different sources of anthropogenic noise associated with the hydrogenation plant. Thereafter, SIP measurements were repeated at the base of the trench. SIP images exhibit two main anomalies: extremely low phase shift values (< 5 mrad) for locations with high BTEX concentrations (> 1000 mg/l) for frequencies below 100 Hz; whereas – in the same frequency range – relatively high polarization values (> 10 mrad) are observed for lower concentrations. Moreover, the phase response shows a constant phase value for the areas with high BTEX concentrations independent of frequency; while the areas with lower concentrations exhibit a typical Cole-Cole response, with a characteristic frequency (given by phase peak) at 0.5 Hz. The observed phase anomalies show agreement with the spatial distribution of contaminants as delineated by water sampling, electrical conductivity logs and analysis of cores collected in the course of direct-push surveys. Computed images for the data collected before and after the excavation of the trench show similar results validating the proposed approach, even in the presence of anthropogenic noise. Based on the results, we conclude that SIP imaging provides useful information to estimate contaminant concentrations; however, more research is required to better understand the observed SIP response and the sensitivity of the frequency-dependent response to specific contaminant processes (e.g., degradation, redox-processes, etc.)