Cross-borehole resistivity tomography: Can it be used to plan and monitor in situ remediation?

Rasmus Thalund-Hansen (rath@env.dtu.dk), Poul L. Bjerg (Technical University of Denmark), Léa Levy, Thue Bording, Anders V. Christiansen (Aarhus University, Denmark), Kirsten Rügge, Morten Dreyer, Lærke Brabæk (COWI, Denmark), Maria T. Hag and Nina Tuxen (Capital Region of Denmark)

Background/Objectives. Evolving in situ methods are showing promising results for sustainable and efficient plume remediation of groundwater contaminations. By injecting reactive components such as oxidation agents, zero valent iron, substrate and/or bacteria, a treatment zone (TZ) is established. In the TZ, the contamination degrades into harmless components by chemical and/or biological processes. Successful in situ remediation depends on contact between injectants and contamination. Yet, monitoring the spreading of the injectant is difficult by point sampling methods. The cross-borehole geophysical method DCIP (Direct Current, Induced Polarisation) allows for detailed spatial information on subsurface electrical resistivity and induced polarisation properties. The information can be used to assess the success of the injection and the development over time. Furthermore, the IP properties can be used to infer spatial information on hydraulic conductivity, which can be used in planning of the in situ remediation and in assessment of contaminant mass discharge (CMD) before and after remediation. The objective of this study is to develop a cost-efficient method for detailed spatial and temporal monitoring of in situ groundwater remediation.

Approach/Activities. A TZ in a contaminant plume of chlorinated ethenes was established in Summer 2019 by injecting the micro zerovalent iron product Provect IR® and a KB1® bacterial culture into the groundwater. A network of 9 geophysical wells with electrodes from 10-20 m.b.s. and 16 monitoring wells over an area of approx. 13x10 m. with a total of 31 screens within 13.5-17.5 m.b.s. was established prior to the injection. Cross-borehole DCIP measurements and water samples were taken before and shortly after injection and during the following year. Intact soil cores were sampled for chemical analysis of iron shortly after injection, and hydraulic tests (slug test, grain size analysis and level specific hydraulic profiles) were done over the TZ depth. Data from water samples, soil cores and hydraulic tests were compared to the geophysical measurements to assess correlation between water chemistry and electrical resistivity from cross-borehole DCIP. The hydraulic properties inferred from hydraulic tests and cross-borehole DCIP were compared. The inferred hydraulic properties and contamination data was used to estimate the CMD from the TZ.

Results/Lesson Learned. A strong correlation was observed between water and geochemistry and electrical resistivity from cross-borehole DCIP. Especially, observed changes in electrical conductivity, total ion strength, calcium, hydrogen carbonate, NVOC and dissolved iron concentrations in water samples and magnetic susceptibility measured on the soil cores matched the geophysical model very well. However, not all observed changes in water and geochemistry showed a clear correlation to the geophysical data. The observed correlation enabled a coherent, detailed understanding of both spatial and temporal spreading of the injected components. A good correlation between hydraulic tests and hydraulic properties inferred from cross borehole DCIP was observed. The overall understanding of injection dynamics and temporal development in the TZ improved largely, by providing coherent and detailed information on water chemistry and hydraulic properties. In this study, the cross borehole DCIP measurements showed that the injectants had not reached the expected distribution, which was only point-wise backed up by water samples. As a consequence, a re-injection was done. Furthermore, using the hydraulic properties inferred from cross borehole DCIP, reduced uncertainty of the estimation of CMD. In conclusion, the results from cross borehole DCIP have the potential to improve planning and monitoring of in situ groundwater remediation.