Monitoring of CO_2-induced geochemical changes in a shallow aquifer by time domain spectral induced polarization

Joseph Doetsch (1), Gianluca Fiandaca (1), Esben Auken (1), Anders V. Christiansen (1), Aaron G. Cahill (2), and Rasmus Jakobsen (3)

(1) HydroGeophysics Group, Department of Geoscience, Aarhus University, Aarhus, Denmark (joseph.doetsch@geo.au.dk),
(2) Department of Environmental Engineering, Technical University of Denmark, Copenhagen, Denmark, (3) GEUS –
Geological Survey of Denmark and Greenland, Copenhagen, Denmark

Contamination of potable groundwater by leaking CO_2 is a potential risk of carbon sequestration. With the help of a field experiment, we investigate if surface monitoring of electrical resistivity and induced polarization can detect geochemical changes induced by CO_2 in a shallow aquifer. For this purpose, we injected CO_2 at a depth of 5 and 10 m and monitored its migration using 320 electrodes on a 126 m × 25 m surface grid. A fully automated acquisition system continuously collected direct current (DC) resistivity and full-decay induced polarization (IP) data and uploaded it into an online database. CO_2 was injected for a period of 72 days and DC/IP monitoring started 20 days before and continued until 120 days after the beginning of the injection. The DC/IP data were supplemented by chemical analysis of water samples collected in 29 wells at time intervals of approximately 10 days.

DC/IP data are inverted using a 2-D algorithm (AarhusInv) that incorporates the full voltage decay of the IP response to resolve DC resistivity, intrinsic chargeability and spectral IP content parameterized using the Cole-Cole model. Borehole information and a baseline inversion reveals the geology at the site consisting of aeolian sands near the surface, glacial sands between 5 and 10 m depth and marine sands below 10 m depth. Following the injection, we use a time-lapse inversion where differences in the DC/IP data are inverted for changes to the Cole-Cole parameters. Two different geochemical signatures that occur due to the injected CO_2 are evident both in the geophysical inversions and the water samples. The first and clearest subsurface signal is a decrease in DC resistivity that moves advectively with the groundwater. The area of resistivity decrease expands with time in the direction of the groundwater flow and there is good correlation between geophysical and geochemical results. A chargeability decrease after the injection has been also observed, but in contrast to the decrease in DC resistivity, the chargeability anomaly remains localized around and slightly downstream of the injection wells throughout the experiment. This chargeability decrease correlates in space and time with a decrease in pH, which is observed in the water samples. Consequently, we attribute this change in chargeability to pH-induced changes to the grains surfaces.

These results highlight the potential for monitoring of field scale geochemical changes by means of surface DC/IP measurements. Especially the different development of the DC resistivity and chargeability anomalies and the different associated geochemical processes, highlight the added value of induced polarization to resistivity monitoring.