CO_2 injection test in a shallow aquifer- feasibility of geoelectrical monitoring

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Understanding the impact of CO_2 on near surface groundwater systems plays a key role for the assessment of effects caused by potential CO_2 intrusions into shallow aquifers. Potential CO_2 intrusion into groundwater can be caused by: (1) naturally occurring geogenic processes and (2) anthropogenic processes, e.g., at air-sparging sites, by potentially leaking geothermal probes that use CO_2 as a heat transfer medium, as well as at CCS sites (Carbon Capture and Storage).
CCS technology is an approach that has the aim of reducing net CO_2 emissions into the atmosphere. However, the availability of efficient methods for detecting and monitoring potential CO_2 degassing in both deep geological formations and the shallow subsurface is a prerequisite for the deployment of CCS, as well as for public acceptance of this technology, which has been the topic of much controversial debate in recent times. Before implementing geological sequestration of CO_2, a sound risk assessment and monitoring strategy is absolutely necessary.
The aim of the presented project is to emulate a CO_2 intrusion scenario by injecting controlled and temporally limited gaseous CO_2 into a shallow aquifer. This field study was performed at a former military air field in north-eastern Germany over a period of 10 days in March and April 2011. One of the main objectives is to develop and test different methods for monitoring CO_2 and/or geochemically altered groundwater (PETER et al., 2012).
Three CO_2 injection wells and 34 monitoring wells in total were installed at the test site up to a depth of approximately 20 m below ground surface level. Monitoring wells were installed along as well as perpendicular to the main groundwater flow direction (Figure 1) and allow for groundwater sampling before, during and after the CO_2 injection period. Additionally, CO_2 injection wells and 33 monitoring wells are equipped with a total of 300 ring-shaped copper electrodes for implementing geoelectrical measurements. The electrodes are installed at pre-defined depths at the outer surface of the well material and allow for high resolution electrical conductivity (inverse of resistivity) monitoring, covering the whole thickness of the sandy CO_2 injection horizon (LAMERT et al., 2012).

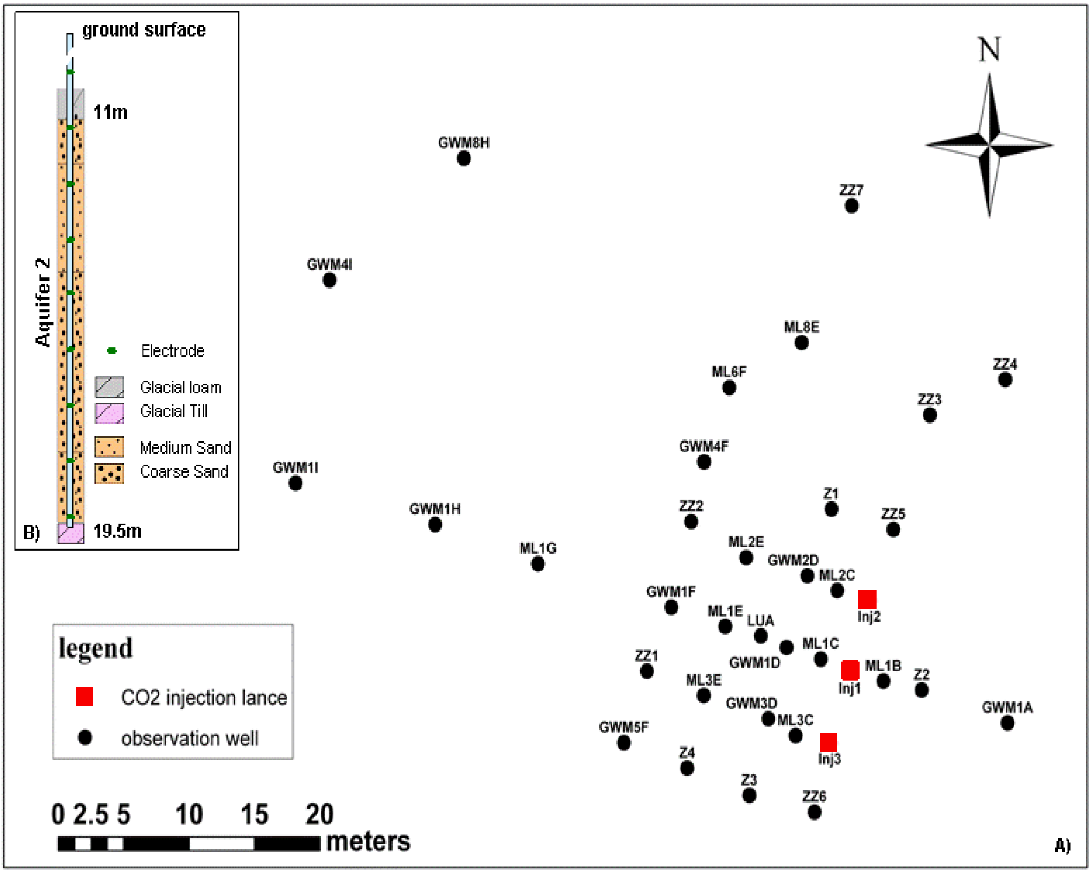

Fig. 1: A) Test site Wittstock. Regional groundwater flow is directed from GWM1A to GWM1 (LAMERT et al., 2012).
B) Schematic geological profile of injection horizon and illustration of a well equipped with electrodes (LAMERT et al., 2012).

Gaseous CO_2 injection into shallow groundwater systems generally causes increased gasphase content in the soil pore space, which accordingly leads to decreased bulk electrical conductivity of the subsurface. However, subsequent dissolution of CO_2 generally leads to decreased pH values and increased electrical fluid conductivity depending on site-specific geological conditions (e.g. presence or absence of buffering materials) and dynamic geochemical processes (e.g. cation-exchange processes).

Breakthrough curves of apparent electrical conductivity (σ_a) show significant variations of σ_a in the order 15 % to 30 % which are affected by the injected CO_2. Groundwater samples are used to validate geoelectrical data. Values for pH and fluid conductivity (σ_f) of groundwater samples (taken from 15 m depth) are exemplarily presented for well ML1E (Figure 2). At well ML1E, pH values decreased from about 6.4 to 5.2 and σ_f of groundwater samples increased from about 500 µS/cm to 800 µS/cm (LAMERT et al., 2012).

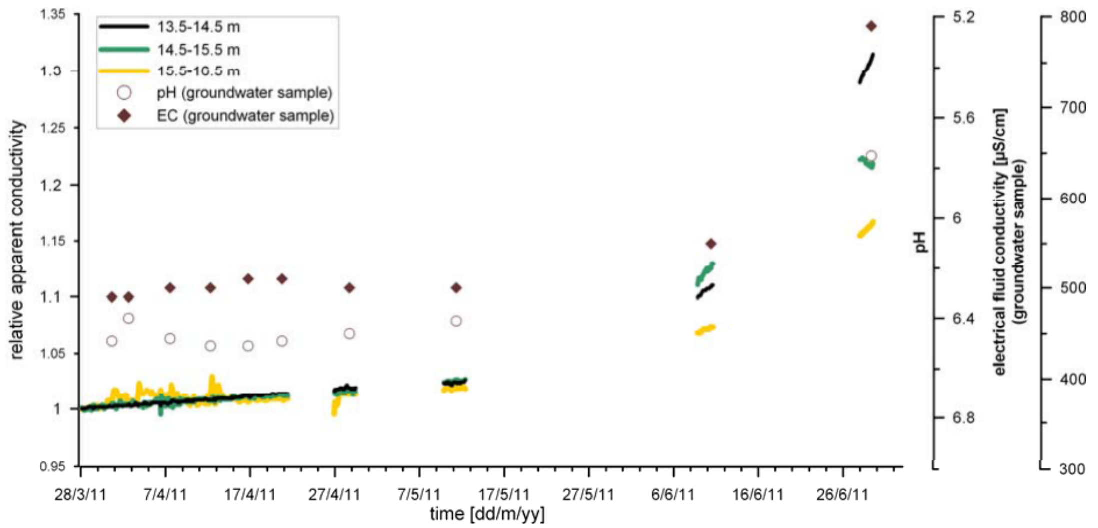

Fig. 2: Field parameters pH and σ_f of groundwater samples (symbols) and temporal variation of apparent electrical conductivity σ_a relative to baseline measurements (solid lines) at well ML1E (1.1" diameter well) for 5 monitoring campaigns performed at the Wittstock site; electrode configuration: Wenner (AMNB). Depths [meter below ground level] of potential electrodes M - N are given in the legend (LAMERT et al., 2012).

In addition to geoelectrical monitoring results, field parameters of groundwater samples also indicate significant alteration in groundwater chemistry caused by the injected CO_2 (PETER et al., 2012). Geoelectrical monitoring results and field parameters are clearly related (Figure 2). This field study has shown the feasibility of geoelectrical measurements for monitoring CO_2 intrusions into shallow aquifers. However, the scope and application of geoelectrical monitoring of CO_2 intrusions strongly depends upon site-specific conditions with respect to dynamic (geochemical) processes, as well as the measuring setup used. The monitoring setup which was used during the presented field experiment permits the detection of small-scale variations in both σ_a (apparent electrical conductivity by geoelectrical breakthrough curves) and σ_f (fluid conductivity of groundwater by groundwater sampling). In order to apply this monitoring strategy at real CCS sites, this approach must therefore be adapted for significantly larger areas, i.e. several km^2.

The presented field study clearly demonstrates that interpretation of geoelectrical breakthrough curves can be used for rapid initial process understanding. However, only using geoelectrical breakthrough curves for comprehensive understanding of gas phase migration processes and the spreading of CO_2 plume in the groundwater is insufficient. Therefore, complementary multiphase simulations should be used. Geoelectrical inversion might be an additional option.

References

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