Inducing a CO2 leak into a shallow aquifer (CO2FieldLab EUROGIA+ project): Monitoring the CO2 plume in groundwaters

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Abstract

An important partof the CO$_2$ capture and storage projects concerns monitoring methods. Here we are focusing on the geochemical monitoring methods that may be deployed at depth to ensure early warning in case of unwanted CO$_2$leakages from a storage site. Independently from the nature of the reservoir (saline aquifer, depleted oil/gas reservoir), aquifers are ubiquitousin the overlying sedimentary pile. Before deploying water monitoring methods at depth, where long-term deployment is still a challenging task, one must be confident with results that are obtained in surface environments.

An ideal way to test such monitoring methods is to deploy them on a site where a CO$_2$ leak is provoked. Pressure effects will certainly not be significant, but deployment in surface environments is a mandatory task to test the real capacity of equipment. This is the case of the Svelvik site located in Norway. Under the auspices of the EUROGIA+ CO2FieldLab project, this site has been instrumented by French, English and Norwegian research teams in order to monitor a CO$_2$ leak using both geophysical and geochemical approaches.Here we focus on the water monitoring methods on these heterogeneous fluvio-glacial deposits with stratified water bodies. Water stratification is a consequence of the presence of infiltrating surface waters, groundwaters, and brackish to saline waters that are influenced by the close Drammen fjord.

The leak was performed at a 20 m depth at the center of a 20 m x 20 m monitoring grid. Water was monitored at 4 different depths, from -15m to -2m. It was also possible to monitor more distant water wells (-5 to -6m depth).Monitoring included low flow water pumping for all the wells and boreholes that allowed following, at a short time scale, physico-chemical parameters of the water (temperature, electrical conductivity, redox potential, dissolved oxygen and pH). Frequent sampling was operatedin order to both determine alkalinity (expressed as bicarbonate content) and to get water for laboratory analyses (dissolved elements and isotopes). Gas contents were also quantified on site bygas chromatography analysis.

The influence of the CO$_2$leak was mainly noticeable on the eastern part of the site, as a result of a skewed injection plan compared to the initial one. Changes were evaluated by comparison with 1 week baseline data acquired prior to the CO$_2$injection. The CO$_2$ influence was observed at all depths. The magnitude of the induced variations depended uponboth the depth and the time of sampling. The main changes concerned water pH with a decrease of up to 2 pH units, electrical conductivity with a 3 to 4 times increase, and bicarbonate contents with again a 3 to 4 times increase. These parameters, plotted as a function of time, allowed, in the most favorable cases, to perfectly identify the CO$_2$ breakthrough that occurred between 2 to 7 days after the beginning of the injection, depending on the sampling location. Similarly, dissolved gas showed a significant modification of abundance ratios, O$_2$ and N$_2$ species being replaced by CO$_2$ during the paroxysm of the leak.

Laboratory analyses performed on one of the most affected level (-10 m depth, eastern part of the site) revealed strong modifications of both major and trace elements contents. Apart from strong a bicarbonate increase, Ca and Fe species did also display an increase of their contents,while Cl and Mg contents were less abundant as a result of local water chemistry and geology. More importantly, regarding the water qualitythematic, remobilization of some undesirable trace elements such as Mn or As was also observed together with strong enrichment factors (up to x60 for Mn). Such enrichments were nevertheless only observed during the paroxysm of the leak, going back to lower values once the leak was stopped. Concentration decreases were element-dependent and more rapid for trace elements than for major elements.

In parallel with these spot acquisitions, continuous recording of water physico-chemical parameters was done in 1 surface well (-2 m depth) using an Idronaut CTD probe. As this equipment was not deployed where the leak showed a strong influence, it did not allow to monitor significant (e.g. pH) changes. Nevertheless, surprisingly, all parameters were affected by the leak as their records exhibited noisy signals even if mean values remained comparable to those determined during baseline acquisitions. For example, the mean pH value was 7.28 ± 0.03 pH units during the baseline; during the leak, the mean pH value is similar (7.37) but with a greater standard deviation (± 0.33 pH unit).

Such records are in agreement with continuous gas records performed at the same location. During the leak, gas records did not show significant deviations from baseline data, but carbon isotope ratios ($\delta^{13}C$) were clearly modified due to the injection process. This is crucial for monitoring protocols that will ensure the safety of future CO_2 storages. Care should be taken as a mean value may not be changed as such, but deviation from this mean value may.