Aquifer-CO2 Leak project: Physicochemical characterization of the CO2 leakage impact on a carbonate shallow freshwater aquifer

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This work is part of the Aquifer CO2-Leak project, started in 2018 for a 4-years duration and that aims at evaluating the impact of CO2 leakages from a geological storage site and developing new monitoring tools and methodologies. The present study aims to understand, quantify and model the environmental impact of a CO2 leak on water quality in the carbonate freshwater aquifer and understanding CO2-water-carbonate interactions.

This research has been performed on an experimental site located in Saint-Emilion (Gironde, France), in an underground quarry within a 30-meter-thick carbonate formation dated to the Upper Oligocene. The facies vary from wackestone to grainstone, and are associated with high values of porosity (from 25 to 45%) and permeability (between 5 and 20 D). A gas mixture, composed of CO2 (90%), He (9%) and Kr (1%), was injected in the aquifer through a borehole located upstream hydraulic gradient. The total injected volume was 200 liters for 1h30.

The seven other boreholes downstream in the injection well were fitted with in-situ probes which automatically measured pH, electrical conductivity, and CO2 fraction. Periodic water samplings have been undertaken, to determine the elementary concentrations by ionic chromatography. The spread of dissolved CO2 in the freshwater aquifer has influenced the physicochemical parameters at the various measurement points and thus has been followed in the time.

The interaction between the CO2 and the limestones causes the dissolution of the calcite, releasing Ca2+ and CO32− in the solution, which are distributed between H2CO3, HCO3−, and CO32−. The comparison of the results before and after the passage of the plume highlights a dissolved CO2 concentration increase, combined with an increase of electrical conductivity and temperature, as well as a decrease in pH values.

The evolution of the physico geochemical signature in the aquifer allow to understand the reactive
and transport processes during a migration of a CO$_2$ plume in a leakage context. The acquisition of these results will make possible to model a leakage in a complex natural reservoir. Electrical conductivity and pH measurements seem to be excellent indicators for monitoring a gas plume during CO$_2$ geological storage. The laboratory analyzes lead to better understand the CO$_2$-water-carbonate interactions produced at the field scale and the relationships with petrophysical properties.

Batch measurements study the evolution of the electrical conductivity, monitored as a function of the CO$_2$ concentrations. Comparison of experiments using only water, water and sand or water and limestone, have shown that only the presence of carbonate ions allows an increase in this geophysical parameter.

By means of these different tools and measures, the propagation of a CO$_2$ leak will be followed through the modification of physicochemical parameters in the aquifer. This should also change the electrical resistivity values across the unsaturated zone. The electrical resistivity tomography should be a complementary tool in order to support these results, and to represent a 3D image plus time of the CO$_2$ plume.