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Consequences of CO_2-rich water intrusion into the Critical Zone

Frédérick Gal and Julie Lions
BRGM, Orléans, France (f.gal@brgm.fr)

From a geochemical point of view, the sensitivity of the Critical Zone to hazards is not only linked to its proximity to the surface. It may also be linked to – albeit less common – intrusion of upward migrating fluids. One of the hazard scenarios to observe these pathways in surface environments is the occurrence of CO_2-rich fluid leakage from deeper horizons and especially leakage from reservoir in the case of underground storage such as Carbon Storage applications. Much effort is done to prevent this risk but it necessary to consider the mitigation of this leak to insure safe storage.
Numerous active or planned CO_2 storage sites belong to large sedimentary basins. In that perspective, a CO_2 injection has been performed in a multi-layered – carbonated aquifer (Beauce aquifer) from the Paris basin as this basin has been considered for such applications. The aquifer mineralogy of the targeted site is dominated by calcite (95 to 98%) with traces of quartz and clay minerals.
Around 10,000 liters of CO_2 were injected at 50 m depth during a series of gaseous pulsed injections for 5 days. After 3 days of incubation in the aquifer, the groundwater was pumped during 5 days allowing the recovery of 140 m3 of backward water. Physico-chemical parameters, major and trace elements concentrations and dissolved CO_2 concentrations were monitored to evaluate water-rock interactions occurring within the aquifer and impacts onto water quality.
Main changes that were observed during the CO_2 release are in good agreement with results from previous experiments performed worldwide. A strong decrease of the pH value (2 units), a rise of the electrical conductivity (2 fold) and changes in the redox conditions (from oxidising to less oxidising) are monitored few hours after the initiation of the pumping. The dissolution of CO_2 induces a drop of pH that favours water-rock interaction processes. The kinetic of reactions appears to be dominated by the dissolution of carbonate, mainly calcite, and probably by desorption processes onto clay minerals. Thus higher concentrations in HCO_3 (+225%), Ca (+95%), Mg (+45%), Na (+14%) and SiO_2 (+11%) as major elements and in Sr, Mn, Ba, B, As or Li as trace elements (2 to 3 fold increase) were monitored. Congruent rise in the concentration in dissolved CO_2 is also observed.
Nonetheless, the effects onto water physico-chemical parameters and water chemistry are transient and vanished in few days (4-5) when pumping is done. In the case of a punctual leakage event, even if pumping was not performed, natural flow of the water will also have induced natural attenuation and progressive vanish of anomalies. From a site management perspective, this suggests that sudden and time limited events may not be noticeable in the near surface if the monitoring locations are located remotely from the source. This highlights the need to have extensive site characterization prior setting a storage site.