Potential hydrogeochemical impacts of CO_2 leakage into shallow aquifers: review and modelling

In case of CO_2 migrating from its reservoir, shallow aquifers could be affected. CO_2 dissolution, water acidification enhancing solubility of minerals, mobilization of heavy metals could represent potential hazards for potable groundwaters.

In order to investigate these phenomena, a review of natural CO_2-water-rocks interactions and modelling works of the hydro-geochemical impact of a CO_2 leak into a shallow aquifer are performed.

Review of natural CO_2-water-rocks interactions in shallow aquifers

> **Natural occurrences** of CO_2-water-rocks interactions (e.g. carbo-gaseous springs) are reported in order to understand :

- potential **groundwater pollution** and **other hazards**
- actual chemical tendencies with **middle to very long term field data**

We gather the following data when available:

- gas properties (composition, fluxes…)
- water properties (pH, pCO_2, salinity, major ions, heavy metals…)
- rocks properties (mineralogical composition…)
- reaction pathways and minerals

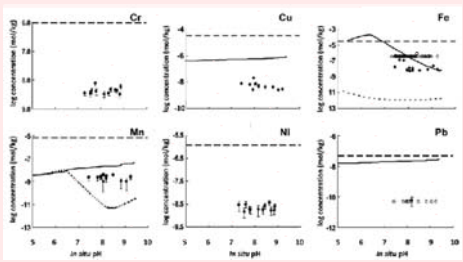

Fig 2 : evolution of toxic metals mobility depending on the pH of a CO_2-enriched groundwater in a basaltic environment. (Flaathen et al., 2009)
Solid curve: modelled reaction path; dotted curve: drinking water limits (Europe); symbols: measured concentration

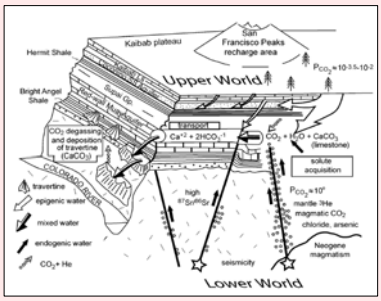

Fig 3 : limestone aquifer generating travertine deposits: influence of CO_2 on water chemistry. (Crossey et al, 2006)

Modelling the impact of a leak into the Albian shallow aquifer (Paris Basin, France)

A modelling case using the Paris basin context:
> **Dogger formation** considered as the storage target
> the overlying **Albian aquifer** considered as the vulnerable layer in case of integrity failure.

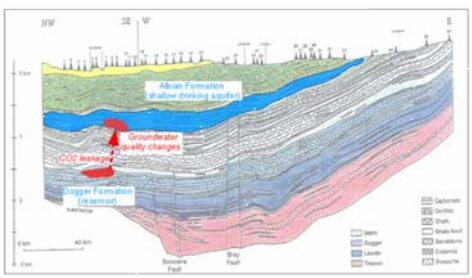

Fig 1 : Geological cross section of the Paris Basin. The Albian aquifer is a strategic water resource overlying the Dogger formation

1. CO_2 Leakage through an abandoned well

> 3D model (fig 4) simulating the evolution of free CO_2 gas saturation during an injection into a storage aquifer and its migration through an abandoned well, located 100 m away from the injection point and connected to an overlying aquifer.

> **Local grid mesh refinement** implemented in the TOUGH2 non isothermal multiphase fluid flow simulator in order to reduce the total number of gridblocks (40 000 gridblocks) and speed up CPU time for calculations.

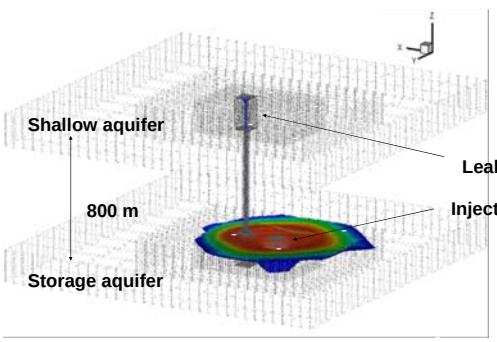

Fig 4 : modelled free CO_2 gas saturation after 10 years of injection

2. Geochemical modelling

> **Batch kinetic tests** using PHREEQC

- Mineralogical context: calcite, dolomite, glauconite, siderite, kaolinite, quartz, muscovite, phosphates. Trace elements are controlled by barite ($BaSO_4$), galena (PbS), greenockite (CdS), chalcocite (Cu_2S), sphalerite (ZnS), rhodochrosite ($MnCO_3$)
- CO_2 entry strongly lowers pH and enhances heavy metals mobility
- In a remote period, toxic elements bearing minerals precipitate as a consequence of pH reequilibration

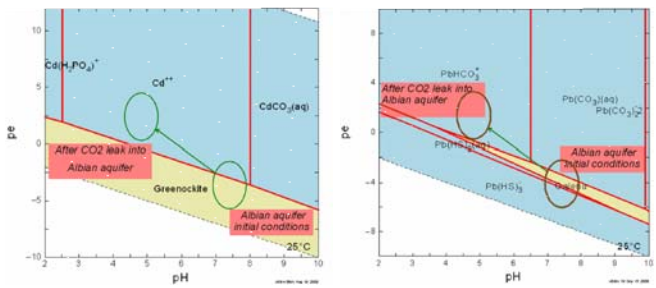

Fig 5 : Cadmium and Lead evolutions in a batch test simulating a CO_2 injection (pCO_2 = 65 bar) Greenockite and Galena are dissolved as a consequence of water acidification.

Further work

The **impacts on water quality** in terms of chemical composition and mineral phase representative of the porous rock will be assessed by estimating fluid rock interactions in both aquifers, using the **reactive transport code** TOUGHREACT. Simulations will aim at:

> Determining the extent and time scale of potential groundwater quality alteration
> Predicting potential trace contamination
> Helping in guidelines definition and criteria selection in the field of environmental risks

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References

Flaathen *et al.* (2009) - Chemical evolution of the Mt. Hekla, Iceland, groundwaters: A natural analogue for CO_2 sequestration in basaltic rocks. Applied Geochemistry, 24, 463–474

Crossey *et al.* (2006) - Dissected hydrologic system at the Grand Canyon: Interaction between deeply derived fluids and plateau aquifer waters in modern springs and travertine. Geology,34(1), 25–28

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