Development of monitoring tools in soil and aquifer for underground H₂ storages and assessment of environmental impacts through an in-situ leakage simulation

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Storing dihydrogen (H₂) underground in salt caverns is seen as a vector of the energy transition. To ensure that risks related to leakage are managed, monitoring methods are needed to detect any H₂ unintended migration. Because the shallow subsurface will act as an ultimate barrier before the gas reaches surface and dwellings, there is also a need to increase knowledge on geochemical impacts of a H₂ leakage on shallow environments.

Geochemical monitoring methods exist and make it possible to detect H₂ directly (H₂ concentrations in dissolved and gaseous phases) or indirectly (e.g. CO₂, O₂, N₂ concentrations in dissolved and gaseous phases, ionic balance and some trace elements, redox potential).

Within the framework of the Rostock'H project funded by the French R&D program GEODENERGIES, a leakage in the shallow subsurface was simulated by injecting water with dissolved H₂ into the aquifer (~20 m deep). Injection was done in November 2019 on a dedicated experimental site and aimed at testing monitoring techniques but also at studying geochemical impacts at very shallow depths. The site is located in the Paris sedimentary basin (Catenoy city). The unconfined aquifer is within the Senonian (Cretaceous) chalk formation. The overlying unsaturated zone includes Bracheux sands (Paleogene) and Quaternary colluvium. The average water table is 12 m deep. The underground water has calcium-bicarbonate facies and a pH close to neutral. Eight piezometers were drilled, aligned over 80 m in the direction of the aquifer main flow (West-East) and slotted between 12 and 25 m deep. Moreover, four dry boreholes were drilled above the piezometric level to monitor the unsaturated zone. Each one was in the close vicinity of a piezometer and slotted between 3 and 11 m deep. The site was equipped with geochemical monitoring tools selected or developed by Ineris and University of Lorraine. For instance, one of the monitoring wells was equipped with a gas completion and connected to a gas RAMAN probe and to a MID IR gas cell with low optical path.

For the experiment purpose, 5 m³ of underground water were pumped, saturated with H₂ at
surface conditions and injected again in the aquifer using one of the piezometers. The \( \text{H}_2 \) injection was preceded by an injection of 1 \( \text{m}^3 \) of underground water saturated with selected chemically inert gas tracer (helium: He) and containing two selected hydrological tracers (uranine and lithium chloride) to anticipate the \( \text{H}_2 \) arrival in the downstream piezometers used as monitoring wells. Dissolved gas concentrations (He, \( \text{H}_2 \), \( \text{N}_2 \), \( \text{O}_2 \), \( \text{CO}_2 \), \( \text{H}_2\text{S} \) and \( \text{CH}_4 \)) were very frequently monitored in situ in the first 4 downstream piezometers (until 20 m from the input well) during the first week. Consequently, the maximum concentrations of dissolved He and \( \text{H}_2 \) were respectively detected 49 hours and 71 hours after the injection started in the piezometer located 10 m downstream the injection well. Moreover, water samples were collected at several time steps to analyze, in laboratory, ionic balance and trace element concentrations in order to assess the environmental impact of a \( \text{H}_2 \) leakage.