Development of monitoring tools in aquifer for underground H₂ storage through an in-situ leakage experiment

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Study aim: Test of monitoring tools for direct/indirect detection of potential H₂ leaks from a deep saline cavern storage into a shallow aquifer (using an experimental site in Paris Basin).
Development of monitoring tools for H₂ direct/indirect detection

Experimental protocol:

1. For continuous gas measurements by 2 combined spectrometry (Raman: H₂, N₂, O₂, CO₂, CH₄, H₂S) and IR: CO₂, CH₄, H₂S) : baseline measurements carried out during six months (May to mid-November, 2019).

2. Injection of 5 m³ of water saturated with H₂ at 1 bar on 19 November 2019 for 2,5 hours.

Profiles of dissolved H₂ as a function of the distance to the well (1)

- \([H_2(aq)]_{\text{max}}\) injected in injection well (PZ2) is 1,78 mg.L\(^{-1}\) (90% of theoretical saturation in 5m\(^3\) tank).

Distance downstream from the injection well where the \([H_2(aq)]_{\text{max}}\) was detected after the injection started:

- At 5m (PZ2 bis), \([H_2(aq)]_{\text{max}}\) (0,6 mg.L\(^{-1}\)) detected after 2 hours by partial degassing method and portable gas analyzer.
- At 7m (PZ2 ter), \([H_2(aq)]_{\text{max}}\) (0,17 mg.L\(^{-1}\)) detected after 9,7 hours and during 19 hours by Raman spectroscopy.

At 20 m upstream (PZ1), no \([H_2(aq)]\) is detected (monitoring well chosen as reference).
No [CH₄(aq)] and no [H₂S(aq)] detected by the portable analyzer used (minimum detection threshold: CH₄ (aq) ~ 1 µg.L⁻¹ and H₂S (aq) = 0.6 µg.L⁻¹).

Distance downstream from the injection well where the [H₂(aq)]ₘₐₓ was detected after the injection started:

- At 10m (PZ3), [H₂(aq)]ₘₐₓ (1.8 µg.L⁻¹) detected after 71 hours by partial degassing method and portable gas analyzer
- At 20m (PZ4), [H₂(aq)]ₘₐₓ (1.8 µg.L⁻¹) detected after 90 hours by partial degassing method and portable gas analyzer

⇒ Migration speed of H₂ plume is 3-5 m.day⁻¹.
Conclusion

• A H₂ leakage simulation has been carried out in a shallow aquifer by injecting 5 m³ of water saturated with H₂ at surface conditions.

• The migration of dissolved H₂ plume was detected and monitored both by continuous method (Raman spectroscopy) and discontinuous measurements (degassing of water samples and analysis using a portable electrochemical gas analyzer).

• Beyond 10 m downstream from the injection well, the H₂ plume migrates at a speed of 3-5 m.day⁻¹ (which is consistent with the natural flow of the aquifer).

Perspectives

Other measurements by continuous monitoring or sampling were performed but data remain to be interpreted more accurately to study their evolution:

▪ Other dissolved gas concentration (CO₂ by Raman, IR and partial degassing - O₂ and N₂ by Raman)
▪ Physico-chemistry (pH, redox potential)
▪ Ionic concentrations of some chemical elements (e.g. sulfates, nitrates)

⇒ It will help to assess the environmental impacts of an H₂ leak into a shallow aquifer.