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Comparison of shallow aquifer and soil gas monitoring approaches for detecting CO₂ leakage at a natural analogue site in France

D. Widory¹, F. Gal¹, E. Proust¹ & B. Mayer²

¹Bureau de Recherches Géologiques et Minières (BRGM), 3 Avenue Claude Guillemin, BP 36009, 45060 Orléans Cedex 2, France

²Department of Geoscience, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada T2N 1N4

Natural analogue sites where geologic CO₂ is leaking to the surface provide excellent opportunities to test approaches suitable for monitoring for potential CO₂ leakage at carbon capture and storage sites. We tested isotope monitoring approaches for CO₂ detection in shallow aquifers and the overlying soil zone at a CO₂ analogue site near Sainte-Marguerite in the Massif Central (France). The Sainte-Marguerite area is located in the southern part of the Limagne graben (French Massif Central). The basement, composed of highly fractured granite, outcrops toward the west of the study area, notably around the Saladis spring. An intercalated arkosic permeable interval between fractured granite and Oligocene marls and limestones acts as a stratiform drain for fluid migration while the overlying thick Oligocene interval is impermeable and acts as a seal. The Allier river bed is located near the contact between the basement and the sedimentary rocks. Deep CO₂-laden fluids migrate through the arkose interval toward the Sainte-Marguerite area and sustain a number of local springs. The Sainte-Marguerite area is known for the travertine deposits associated with the CO₂-rich natural springs.

We collected water samples and effervescent gases at the springs as well as soil gases for chemical and isotopic analyses. The analytical parameters included major anions and cations, $\delta^{13}\text{C}$ & $\delta^{18}\text{O}$ of CO₂, δD & $\delta^{18}\text{O}$ of H₂O and $\delta^{13}\text{C}$ of dissolved inorganic carbon (DIC). Preliminary results revealed that $\delta^{13}\text{C}$ values of CO₂ in most groundwater and soil samples were similar. Oxygen isotope measurements revealed equilibrium between CO₂ and H₂O-oxygen in most samples, but except for a limited number of samples, $\delta^{18}\text{O}$ values of water did not deviate significantly from the local meteoric water line. Our preliminary results suggest that both the groundwater and the soil sampling approaches should be capable of detecting leakage of CO₂ provided that the leaking gas has a distinct isotopic composition. The thresholds of leakage detection are currently determined in laboratory column experiments, where CO₂ of known isotopic composition is bubbled through a water-saturated sand at different rates and continuously measured for its $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ isotope composition using laser spectroscopy. The potential for isotope exchange between oxygen from water and oxygen from bubbling CO₂ is also evaluated.