



HAL
open science

CO₂ -Vadose and DEMO-CO₂ Projects: Two Complementary Projects about Geochemical and Geophysical Monitoring During CO₂ Leakage

B. Garcia, K. Rhino, C. Loisy, O. Le Roux, Adrian Cerepi, V. Rouchon, S. Noirez, C. Le Gallo, Ph. Delaplace, O. Willequet, et al.

► **To cite this version:**

B. Garcia, K. Rhino, C. Loisy, O. Le Roux, Adrian Cerepi, et al.. CO₂ -Vadose and DEMO-CO₂ Projects: Two Complementary Projects about Geochemical and Geophysical Monitoring During CO₂ Leakage. Energy Procedia, 2017, 114, pp.3695 - 3698. 10.1016/j.egypro.2017.03.1500 . hal-01739930

HAL Id: hal-01739930

<https://ifp.hal.science/hal-01739930>

Submitted on 21 Mar 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License



13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18
November 2016, Lausanne, Switzerland

CO₂-Vadose and DEMO-CO₂ projects: two complementary projects about geochemical and geophysical monitoring during CO₂ leakage

B. Garcia^{a*}, K. Rhino^b, C. Loisy^b, O. Le Roux^b, A. Cerepi^b, V. Rouchon^a, S. Noirez^a, C. Le Gallo^a, Ph. Delaplace^a, O. Willequet^c, C. Bertrand^d

^aIFPEN, Geosciences Division, Geofluids and Rocks department, 1&4 avenue de Bois Préau, 92852 Rueil-Malmaison, France

^bEA 4592, « Géoressources et Environnement », ENSEGID-Bordeaux INP, 1 allée F. Daguin, 33607 Pessac cedex, France

^cDIMELCO, 156 rue des Famards – CRT2 – CS 10210 Fretin, France

^dALGADE, Avenue du Brugeaud, 87250 Bessines-sur-Gartampe, France

Abstract

From a natural underground cavity and two locations situated in a well, three CO₂ injections have been designed and performed under controlled conditions in order to study its migration along the carbonate vadose zone and to test geochemical and geophysical techniques. After the understanding of the natural CO₂ dynamics and the establishment of a baseline, some numerical simulations have been performed to help to optimize the monitoring strategy (spatially and temporally). A mixture of CO₂ + noble gases has been injected and the results show that CO₂ subsurface leakage can be anticipated thanks to these inert chemical gases used as tracers (He + Kr). The geochemical and geophysical monitoring approaches are very complementary.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: CO₂ ; noble gases ; inert gas ; geochemical and geophysical monitoring ; numerical simulations ; carbonate vadose zone

* Corresponding author. Tel.: +33-1-47-52-53-17; fax: +33-1-47-52-70-19.

E-mail address: bruno.garcia@ifpen.fr

1. Introduction

Capturing CO₂ and injecting it into deep underground geologic formation currently presents great interest, as it is one of the solution susceptible to decrease the accumulation of greenhouse gas into the atmosphere. Carbon capture and storage site (CCS) are subjected to specification relative to security towards population but also toward the environment. As consequences, it has been suggested that a maximum of 0.01 % per year of CO₂ leakage would be the maximum amount of CO₂ tolerated to leak from a CCS site [1, 2]. Therefore geochemical tools have to be developed to monitor and detect CO₂ leakage from the near surface and the shallow unsaturated zone (vadose zone). They must have the potential to precisely detect and quantify leaks, and discriminate natural signal from anthropogenic ones.

Monitoring CO₂ soil gas has been intensively studied for the last years [e.g. 3, 4, 5]. As example, [6] used particularly some gas tracers as precursors of the CO₂ leakage and to identify the origin of CO₂ detected. Those gas tracers are chosen to be chemically inert and with higher diffusion coefficient in order to be displaced faster than CO₂. It demonstrates the need of having precursors to predict preferential path or heterogeneity of the massive. Indeed, [7, 8] and [9] presented studies with specific isotope signature such as δ¹³CO₂. [10] presents isotopic tools as ways to determine predominant process during the leakage. They could monitor mixing processes and measure its associated chemical mechanism. However, each approach converges towards the same complex combination of geochemical mechanism occurring in the vadose zone [11]. In order to understand CO₂ dynamics during a potential leakage, it is then important to study different pattern of a release and the different factor susceptible to affect CO₂ mobility.

2. Method and/or theory with main results

Release experiment has been performed at Saint Emilion (France) in order to estimate the contribution of parameters in CO₂ dynamic. Thus, [12] injected at 9 m depth a CO₂ - rich gas mixture with associated gas tracers (He and Kr) from a cavity in the limestone and observed differences between the numerical model and field data. It emphasized the difficulty in building geological model relevant to diffuse migration of gases at decameter scale. The definition of the gas plume was successful.

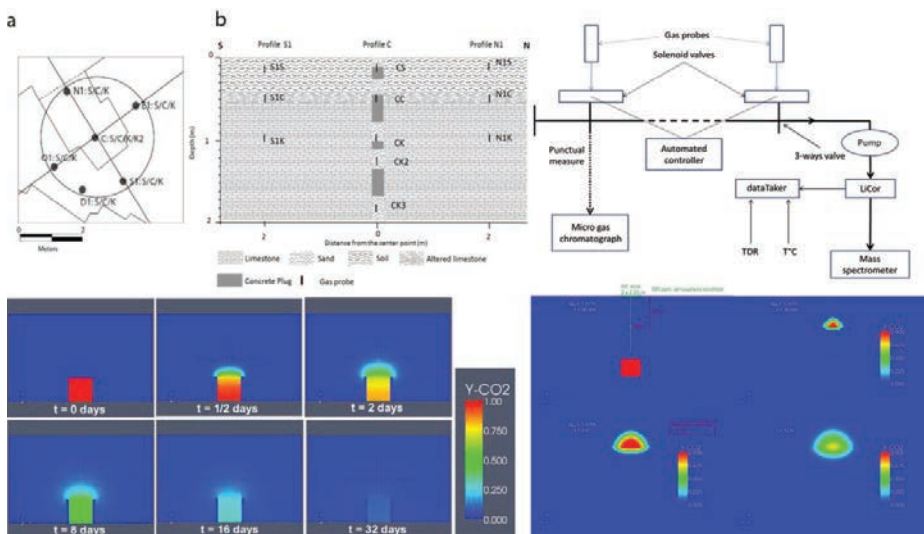


Fig. 1. (top) Map of gas probes implementation on the experimental site and schematic representation of the gas analyses device; (bottom) Numerical simulations of CO₂ leakage from the cavity (left) and from the CK4 point in the well (right).

However, differences in timing and amplitude were noticed, especially for the CO_2 where the major difference was observed. Indeed, between numerical simulation and experiments, the difference concerning the CO_2 is equal to 21 days for the peak arrival and 1400% for the maximum concentration observed for the probes near the injection point for example; whereas the differences concerning the He and Kr are not more than 3.7 days for the peak arrival and 600% for the concentration.

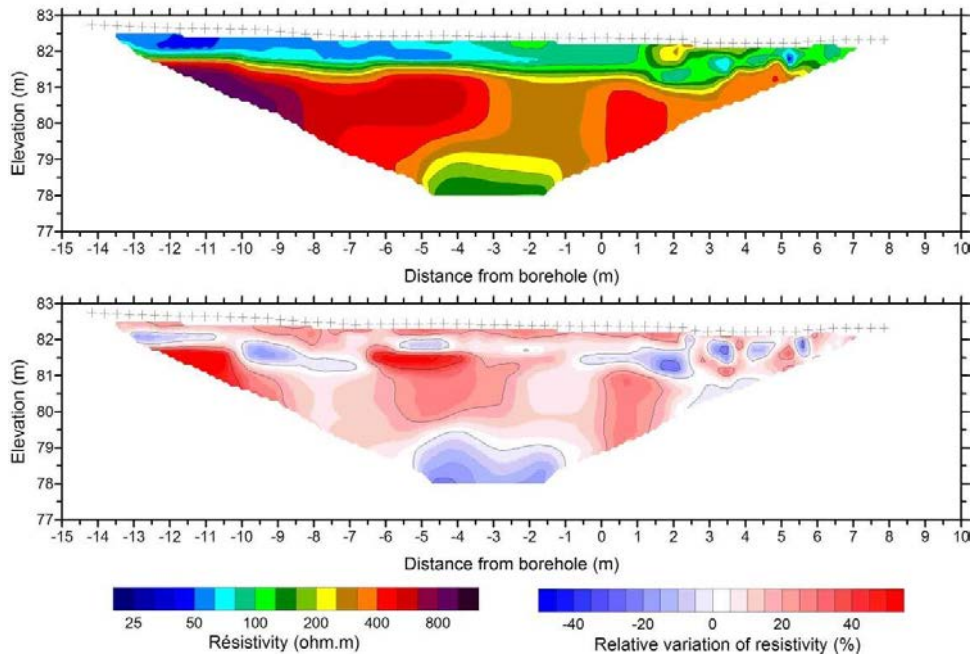


Fig. 2. Evolution of the resistivity traducing CO_2 concentration variation within the Southwest-Northeast transect of the vadose zone within the limestone.

In the same pilot site, [11] performed a release experiment of enriched CO_2 mixture with noble gases at 3.7 m depth but with a pressure of 2 bar, through a well. Both diffusive and convective transport were observed. It also showed that difference of peak arrival time of noble gases and CO_2 could give more information about the dominance of either diffusion or advection processes. In the case of diffusion, displacement would be a function of molecular weight hence it could lead to presence of difference in molecular speed.

Nevertheless, there are few studies on the interaction occurring between the storage formation and the gas phase. [1] explained in their study that depending of the type of release, attenuation efficiency of the unsaturated zone could be drastically different. Higher pressures surrounding the source zone could cause more vertical migration of the CO_2 . Interactions between CO_2 and water phase can complicate attenuation dynamic. [6] explain that this is due to the inherent anisotropy of the system, but also to the lack of fundamental understandings on actual rock- CO_2 -water interaction.

3. Conclusions

The aim of this study is to understand the attenuation mechanism in the carbonate vadose zone and to estimate the processes of transport and reaction. This work describes the results of a release experiment in the shallow surface of the vadose zone. Then, the results obtained here are compared to a former leakage experiment which was also performed slightly deeper in the limestone with higher injection flow rate [11]. Spatial and temporal variation was continuously monitored thanks to a set of probes placed at different depth. Soil flux, water content and climatic parameters were also regularly measured. This work describes the methods and tools used to continuously monitor the CO₂ plume.

Acknowledgements

IFPEN and ENSEGID-Bordeaux INP thank ADEME for their funding.

References

- [1] Oldenburg CM, and Lewicki JL. On leakage and seepage of CO₂ from geologic storage sites into surface water. *Environ. Geol.* 2003;50:691–705.
- [2] White CM., Strazisar BR, Granite EJ, Hoffman JS, Pennline HW. Separation and capture of CO₂ from large stationary sources and sequestration in geological formations coalbeds and deep saline aquifers. *J Air & Waste Man. Ass.* 2003;53:645–715.
- [3] Beaubien SE, Jones DG, Gal F, Barkwith AKAP, Braibant G, Baubron J-C, Ciotoli G, Graziani S, Lister TR, Lombardi S. Monitoring of near-surface gas geochemistry at the Weyburn, Canada, CO₂-EOR site, 2001–2011. *IJGGC* 2013; 16: S236–S262.
- [4] Gal F, Michel K, Pokryszka Z, Lafortune S, Garcia B, Rouchon V, de Donato P, Pironon J, Barres O, Taquet N. Study of the environmental variability of gaseous emanations over a CO₂ injection pilot—Application to the French Pyrenean foreland. *IJGGC* 2014; 21:177–190.
- [5] Lewicki JL, Oldenburg CM, Dobeck L, and Spangler L. Surface CO₂ leakage during two shallow subsurface CO₂ releases. *GRL.* 2007; 34.
- [6] Myers M, Stalker L, Pejic B, Ross A. Tracers – Past, present and future applications in CO₂ geosequestration. *App. Geochem.* 2007;30:125–135.
- [7] Garcia B, Hy Billiot J, Rouchon V, Mouronval G, Lescanne M, Lachet V, Aimard N. A Geochemical Approach for Monitoring a CO₂ Pilot Site: Rousse, France. A Major gases, CO₂-carbon isotopes and Noble Gases Combined Approach. *OGST* 2014; 67:341-353.
- [8] Garcia B, Delaplace P, Rouchon V, Magnier C, Loisy C, Cohen G, Laveuf C, Le Roux O, and Cerepi A. The CO₂-vadose project: Numerical modeling to perform a geochemical monitoring methodology and baseline performance assessment for various geochemical variables (gas flux, gas composition, stable isotopes and noble gases) in the carbonate vadose zone. *IJGGC.* 2013;14: 247–258.
- [9] Nickerson N, Risk D. Using subsurface CO₂ concentrations and isotopologues to identify CO₂ seepage from CCS/CO₂-EOR sites: A signal-to-noise based analysis. *IJGGC.* 2013;14:239–246.
- [10] Humez P, Négrel P, Lagneau V, Lions J, Kloppmann W, Gal F, Millot R, Guerrot C, Flehoc C, Widory D. CO₂-water-mineral reactions during CO₂ leakage: Geochemical and isotopic monitoring of a CO₂ injection field test. *Chem. Geol.* 2014;368:11–30.
- [11] Rillard J, Loisy C, Le Roux O, Cerepi A, Garcia B, Noirez S, Rouchon V, Delaplace P, Willequet O, Bertrand C. The DEMO-CO₂ project: A vadose zone CO₂ and tracer leakage field experiment. *IJGGC.* 2015;39:302–317.
- [12] Cohen G, Loisy C, Laveuf C, Le Roux O, Delaplace P, Magnier C, Rouchon V, Garcia B, Cerepi A. The CO₂-Vadose project: Experimental study and modeling of CO₂ induced leakage and tracers associated in the carbonate vadose zone. *IJGGC.* 2013; 14:128–140.