Diffuse soil CO_2 flux to assess the reliability of CO_2 storage in the Mazarrón-Gañuelas Tertiary basin (Spain)

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Abstract

Geological storage of CO_2 is nowadays internationally considered as the most effective method for greenhouse gas emission mitigation, in order to minimize its effects on the global climatology. One of the main options is to store the CO_2 in deep saline aquifers at more than 800 m depth, because it achieves its supercritical state. Among the most important aspects concerning the performance assessment of a deep CO_2 geological repository is the evaluation of the CO_2 leakage rate from the chosen storage geological formation. Therefore, it is absolutely necessary to increase the knowledge on the interaction among CO_2, storage and sealing formations, as well as on the flow paths for CO_2 and the physico-mechanical resistance of the sealing formation. Furthermore, the quantification of the CO_2 leakage rate is essential to evaluate its effects on the environment. One way to achieve this objective is to study of CO_2 leakage on natural analogue systems, because they can provide useful information about the natural performance of the CO_2, which can be applied to an artificial CO_2 geological storage.

This work is focused on the retention capacity of the cap-rock by measuring the diffuse soil CO_2 flux in a site selected based on: i) the presence of a natural and deep CO_2 accumulation; ii) its structural geological characteristics; and iii) the nature of the cap-

rocks. This site is located in the so-called Mazarrón-Gañuelas Tertiary Basin, in the Guadalentin Valley, province of Murcia (Spain)

Therefore the main objective of this investigation has been to detect the possible leakages of CO_2 from a deep saline aquifer to the surface in order to understand the capability of this area as a natural analogue for Carbon Capture and Sequestration (CCS).

The results obtained allow to conclude that the geological sealing formation of the basin seems to be appropriate to avoid CO_2 leakages from the storage formation.

1. Introduction

The scientific community has general accepted that long-term extrapolation in terms of safety of a deep geological storage of toxic industrial wastes, such as high activity radioactive wastes, industrial and mining wastes and even greenhouse gases, can not be satisfactorily done on the basis of short term researches in the laboratory [1]. Therefore, countries affected by these problems have developed methods of investigation which include both short-term tests in the laboratory, where the variables are controlled, as the study of natural analogues.

Although the studies about CO_2 natural accumulations are not yet sufficiently developed, some authors [2,3] have included in their works the existing CO_2 reservoirs in the world and the experimental reactions between CO_2 and the storage formations [4]. Moreover, in the last decade there are many works focused on the evaluation of the safety of a CO_2 geological storage by means of the study of CO_2 leakage natural analogues [5-11].

Regarding Spain, there's one current important project cofunded by the Ministry of Science and Innovation and FEDER European Funds, whose main objective is the global study of the several CO_2 natural analogues in all over the country. Among them, the natural analogue of storage, and natural and artificial leakage of CO_2 located in the – Gañuelas-Mazarrón Tertiary basin (Province of Murcia) is being studied by the CIEMAT reseach team (Fig. 1). The CO_2 diffuse flux in the soil by means of a WEST-

SYSTEMS fluxmeter has been performed in the above-mentioned site, in order to know whether the cap-rock is able to retain possible escapes of CO_2 at the surface.

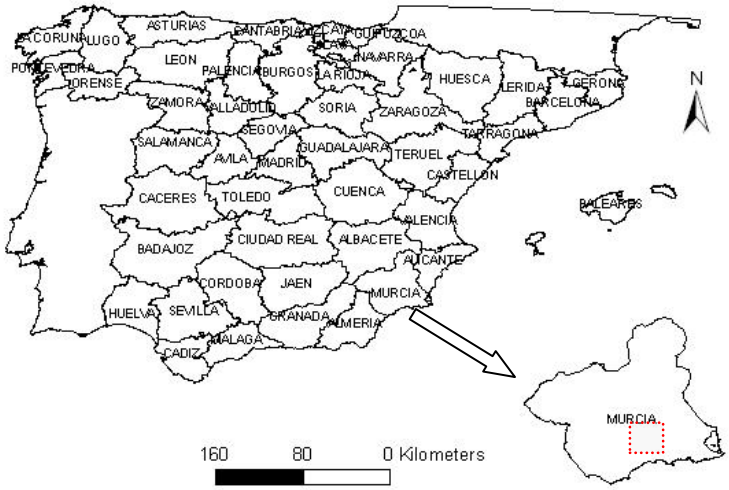


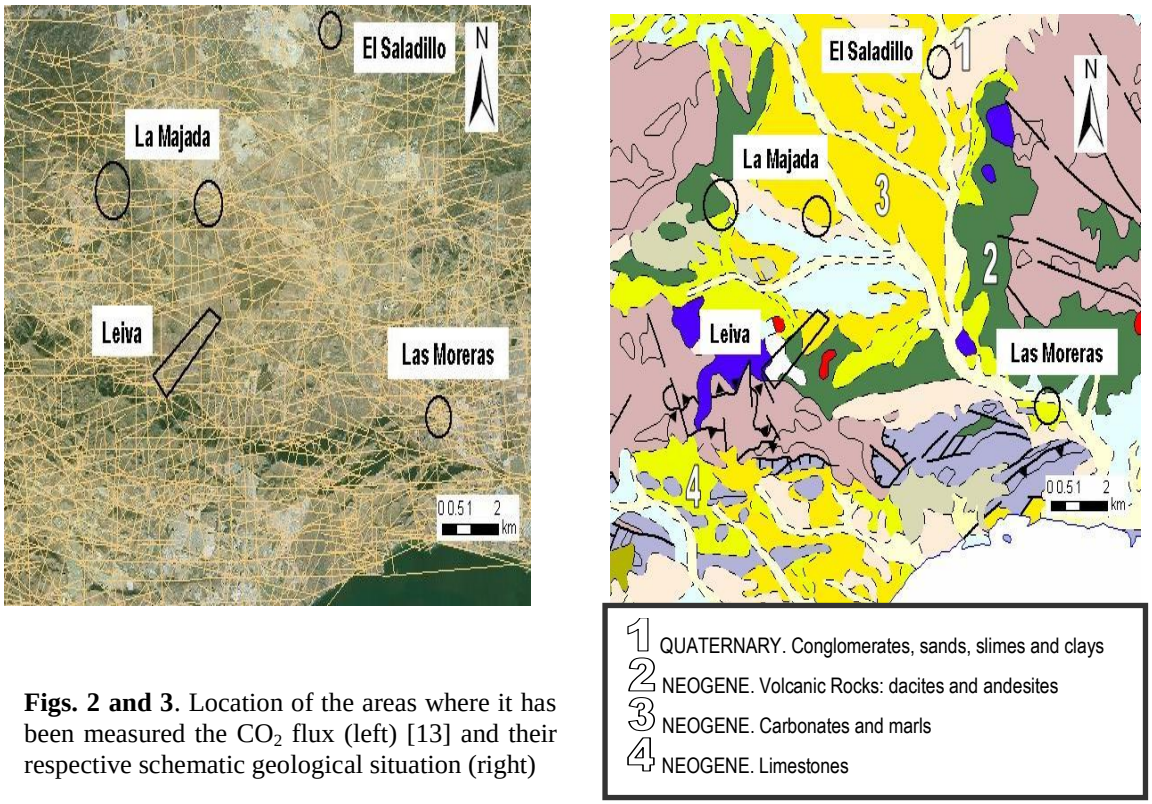
Fig. 1. Geographical location of the study area (red square)

2. Experimental section

In the Gañuelas-Mazarrón Tertiary basin, according to the structural geological features [12,13], four areas were selected for a comprehensive CO_2 flux study. They are located at the intersection of high density lineaments (Fig. 2) that should likely correspond to preferential leakage paths of deep-seated CO_2. These areas are: Las Moreras, La Majada and Leiva (Fig. 3), which are at the contact between the Tertiary basin and the Triassic surroundings mountains, and the El Saladillo place, situated inside the Gañuelas-Mazarrón basin.

The equipment used for CO_2 flux measurements is that licensed by West-System and consists in an accumulation chamber from where the soil gas is forced to be pumped through an IR cell set at the wavelength of CO_2. The increase of CO_2 with time allows the measurement of the flux by means an algorithm that takes into account the pressure and temperature data collected in the field [14].

The CO_2 soil fluxes were carried out in September 2009 and March 2010 during dry and meteorologically stable periods in order to avoid the possible influence of variations induced by environmental parameters on soil degassing. Laboratory experiments were performed to assess both, the reliability of CO_2 flux measurements and the calibration of the instrument [14].



Figs. 2 and 3. Location of the areas where it has been measured the CO_2 flux (left) [13] and their respective schematic geological situation (right)

3. Results and Discussion

In September 2009 the CO_2 flux soil was computed for a surface of ~52,700 m^2 in Las Moreras; ~86,800 m^2 in La Majada; ~179,600 m^2 in Leiva; and ~136,000 m^2 in El Saladillo. In these areas, 127, 277, 257 and 187 evenly distributed measurements were done, respectively. In March 2010, the investigation in La Majada and Leiva areas was enlarged with 93 and 94 measurements, covering additional surfaces of ~39,000 m^2 and 30,000 m^2, respectively.

The measured φCO_2 at Las Moreras oscillates from 0.007 to 0.929 moles m^{-2} day^{-1}, with an average value of 0.262 moles m^{-2} day^{-1}, while at El Saladillo they were spanning between 0.020 and 1.103 moles m^{-2} day^{-1}, with an average value of 0.353 moles m^{-2} day^{-1}. At La Majada a large interval of variation was observed in September 2009, ranging from

0.007 to 7.503 moles m^{-2} day^{-1}, with an average value of 0.877 moles m^{-2} day^{-1}; whereas, in March 2010, a lower interval, between 0.025 and 1.425 moles m^{-2} day^{-1}, was observed, being its average value of 0.456 moles m^{-2} day^{-1}. Finally, at Leiva the φCO_2 values varied between 0.024 and 1.490 moles m^{-2} day^{-1}, with an average value of 0.391 moles m^{-2} day^{-1} (September 2009) and between 0.041 and 1.074 moles m^{-2} day^{-1} with an average value of 0.310 moles m^{-2} day^{-1} (March 2010).

In order to better constrain the total φCO_2 and the CO_2 spatial distribution overall the investigated areas, the values are divided in populations according to the method proposed by Sinclair [15]. The diffuse φCO_2 values in the four investigated areas were lower than 1.0 moles m^{-2} day^{-1}, whereas values up to 7.5 and 1.49 moles m^{-2} day^{-1} were measured in September 2009 at the La Majada and Leiva areas, respectively. It is worthy to mention that φCO_2 values higher than 1 moles m^{-2} day^{-1} were only sporadically recorded.

4. Conclusions

On the basis of the diffuse soil CO_2 degassing surveys carried out in September 2009 and March 2010, the general picture emerging from the present study is that in the area under study, although characterized by a complex geological setting, the efficiency of the cap-rock, as sealing formation, in the Gañuelas-Mazarrón Tertiary basin does not allow any relevant CO_2 leakages at the surface. That is, in terms of CO_2 soil flux, the Tertiary sedimentary deposits filling the basin act then as an impermeable layer through which the escape of CO_2 is not jeopardized. This is strongly supported by the measurements of the φCO_2 carried out by means of the accumulation chamber method. The investigated areas have generally low φCO_2. They are basically comparable to those observed in cultivated areas worldwide, with very few exceptions that can possibly be related to structural weakness or fault zones. Nevertheless, this statement is not sufficiently supported by the available data. It is however matter of fact that the geological sealing formation results to be effective and efficient in case of any leakage of CO_2.

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References

[1] Petit JC. Reasoning by analogy : rational foundation of natural analogue studies. Appl. Geochem 1992; Supplementary Issue 1:9-12.

[2] Czernichowski-Lauriol I, Sanjuan B, Rochelle C, Bateman K, Pearce J, Blackwell P. The underground disposal of carbon dioxide. In: Holloway S, editor. Inorganic Geochemistry. Final Report of Joule II Project Nº CT92-0031.

[3] Pearce JM, Holloway S, Wacker H, Nelis MK, Rochelle C, Bateman K. Natural occurrences as analogues for the geological disposal of carbon dioxide. Energy Converse and Management 1996;37:6-8.

[4] Pearce JM, Rochelle C. CO_2 storage: mineral reactions and their influences on reservoir permeability. A comparison of laboratory and field studies. Elsevier; 1999.

[5] Czernichowski-Lauriol I, Pauwels H, Vigouroux P, Le Nindre YM. The french carbogaseous province: an illustration of natural processes of CO_2 generation, migration, accumulation and leakage. Greenhouse Gas Control Technologies. Vols I and II, Proceedings 2003;411-416.

[6] Hawkins, DG. No exit: thinking about leakage from geologic carbon storage sites. Energy 2004;29:1571-1578.

[7] Beaubien SE, Lombardi S, Ciotoli G, Annuziatellis A, Hatziyannis G, Metaxas A et al. Potential hazards of CO_2 leakage in storage systems-Learning from natural systems. Greenhouse Gas Control Technologies 2005;7:551-560.

[8] Nordbotten JM, Celia MA, Bachu S, Dahle HK. Semianalytical solution for CO_2 leakage through an abandoned well. Environmental Science & Technology 2005;39: 602-611.

[9] Oldenburg CM, Lewicki JL. On leakage and seepage of CO_2 from geologic storage sites into surface water. Environmental Geology 2006;50:691-705.

[10] Riding JB. The IEA Weyburn CO_2 monitoring and storage project - Integrated results from Europe. Advances in the Geological Storage of Carbon Dioxide: International Approaches to Reduce Anthropogenic Greenhouse Gas Emissions 2006;65:223-230.

[11] Lewicki JL, Birkholzer J, Tsang CF. Natural and industrial analogues for leakage of CO_2 from storage reservoirs: identification of features, events, and processes and lessons learned. Environmental Geology 2007;52:457-467.

[12] Pérez del Villar L, Pelayo M, Recreo F. Análogos Naturales del Almacenamiento Geológico de CO_2 (Fundamentos, Ejemplos y Aplicaciones para la Predicción de Riesgos y la Evaluación del Comportamiento a Largo Plazo). CIEMAT; 2007.

[13] Pérez del Villar L. Memoria Científico-Técnica del periodo 2008-2009 del PSE-120000-2008-6 (PSS-120000-2008-31). Línea de Análogos Naturales: "Resultados preliminares del estudio de los análogos naturales estudiados en: la región de La Selva (Girona), Valle del Alto Guadalentín (Murcia-Almería), Alicún de las Torres (Granada), Alhama de Aragón-Járaba (Zaragoza) y Castilla León" CIEMAT; 2009.

[14] Nisi B, Vaselli O, Lelli M, Tassi F, Rodrigo-Naharro J, Pérez del Villar L. Diffuse CO_2 flux and dissolved gases in the Mazarrón-Gañuelas area (Guadalentin Valley). Report PSE; 2010.

[15] Sinclair AJ. Selection of threshold values in geochemical data using probability graphs. Geochem. Expl. 1974;3:129-149.