The application of noble gases and carbon stable isotopes in tracing the fate, migration and storage of CO_2

Stuart Gilfillan[1], Stuart Haszedline[1], Fin Stuart[2], Domokos Gyore[2], Rachel Kilgallon[1], Mark Wilkinson[1]

[1]School of GeoSciences, University of Edinburgh, Edinburgh, EH9 3JW, Scotland, UK

[2]Isotope Geoscience Unit, Scottish Universities Environmental Research Centre (SUERC), University of Glasgow, East Kilbride, G75 0QF, Scotland, UK

Abstract

CO_2 capture and subsequent geological storage of CO_2 is an industrially proven means of abating anthropogenic CO_2 emissions from point sources. For the technology to be universally deployed it is essential that a robust, reliable and inexpensive means to trace the migration and fate of the CO_2 injected into the subsurface exists[1]. Monitoring during injection will increase confidence that the site characteristics were correctly determined and met. Furthermore, should unplanned migration from the storage site occur, the ability to identify the origin and ownership of CO_2 at near and ground surface will be critical in differentiating the migrated CO_2 from natural background levels, enabling remediate actions to be instigated[1].

The noble gases (He, Ne, Ar, Kr and Xe) are present in trace quantities in all natural and engineered CO_2. There are three distinct sources of noble gases in subsurface fluids (namely crust, mantle and atmosphere) which are isotopically distinct. Further, they are inert and are not affected by chemical reactions in the reservoir. Consequently the noble gases are extremely powerful tracers of both the CO_2 source, and when combined with carbon stable isotopes, the subsurface processes that control the fate of CO_2.

We will present a summary of the progress made over the past decade in using noble gases and stable carbon isotope tracing techniques in CO_2 storage studies. This will include a comparison of recently obtained noble gas and C isotope data from the Cranfield CO_2-EOR reservoir (MS, USA) with previous work undertaken on natural CO_2 reservoirs from around the globe[2,3]. Our results illustrate that good progress has been made in using noble gases to determine both the short-term and long-term fate of CO_2 in the subsurface and in the determination of the extent of groundwater interaction that the injected CO_2 has undergone.

We will also provide a review of the work which used noble gases for monitoring of natural subsurface CO_2 migration to the near surface in CO_2 rich soils, CO_2 rich springs and groundwaters. We will demonstrate how natural noble gas fingerprints were used to trace CO_2 dissolved in the groundwater migrating through the subsurface to the surface above the St. Johns Dome natural CO_2 reservoir in Arizona[4] and to detect the micro-seepage of CO_2 and CH_4 above the Teapot Dome oil field in Wyoming[5].

We show that similar methods effectively ruled out allegations of the leakage of CO_2 into groundwater wells surrounding the Kerr Farm[6], located near Goodwater in Saskatchewan, close to the Weyburn-Midale CO_2-EOR field. We found that there was no presence of deep crustal derived noble gases within the groundwaters surrounding the Kerr Farm. The absence of this crustal component helped to show that there was no evidence of the migration of CO_2 from the Weyburn oil field into the groundwater on the Kerr Farm or surrounding area.

Lastly, we will document experimental work which is underway to further constrain the factors and processes involved in noble gas and CO_2 transport. Experimental equipment constructed at Edinburgh is being used to determine the factors affecting the transport of noble gases relative to CO_2. This work aims to investigate how noble gases could be used as effective early warning tracers of CO_2 migration in engineered CO_2 storage sites.

Given the breadth of the applications of noble gases in CO_2 storage and monitoring it is imperative that the progress made in this field is continued. It is therefore essential that future pilot and early industrial scale CO_2 injection studies continue to investigate the behaviour of noble gases in the subsurface in order to help develop suitable noble gas monitoring strategies for universal deployment in the future.

References

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