COMPARISON OF THE IMPACTS OF ELEVATED CO_2 SOIL GAS CONCENTRATIONS ON SELECTED EUROPEAN TERRESTRIAL ENVIRONMENTS

J. M. West[1*], D. G. Jones[1], A Annunziatellis[2], T. S. Barlow[1], S. E. Beaubien[2], N. Breward[1], P. Coombs[1], D. de Angelis[2], A. Gardner[1], V. Gemeni[3], S. Graziani[2], K. A. Green[1], S. Gregory[1], S. Gwosdz[4], S. Hannis[1], N. Koukouzas[3], M. Krüger[4], S. Libertini[2], T.R. Lister[1], S. Lombardi[2], K. L. Smith[5], M. D. Steven[5] and F. Ziogou[3].

[1]British Geological Survey, Keyworth, Nottingham NG12 5GG, UK.
[2]Universita di Roma "La Sapienza", Rome, Italy.
[3]CERTH/Chemical Process and Energy Resources Institute, Thessaloniki 57 001, Greece.
[4]Federal Insitute for Geosciences and Natural Resources, 30655 Hannover, Germany.
[5]University of Nottingham, School of Geography, Nottingham, UK.
Corresponding author's e-mail address: *jmwes@bgs.ac.uk

Keywords CO_2 storage; leakage; site monitoring; leakage detection; natural systems; controlled injection; environmental impacts

ABSTRACT

Carbon dioxide capture and storage is one option for reducing man-made greenhouse gas emissions to the atmosphere. However, the possibility of leakage from the reservoir, and any subsequent effects on the environment, need to be considered. Consequently, the impact of elevated CO_2 soil gas concentrations on near-surface ecosystems (to a depth of ~1 m) has been an area of active research for a number of years, particularly in the context of terrestrial systems, and is currently being addressed as part of the FP7 RISCS (Research into Impacts and Safety in CO_2 storage) project. In Europe terrestrial studies have targeted natural sites which are being used as pasture, where CO_2 is being released to the atmosphere from deep geological formations (e.g. Florina, Greece (Ziogou et al, in press); Laacher See, Germany (Krüger et al, 2011); Latera, Italy; (Beaubien et al, 2008)); and pristine non-adapted sites where CO_2 is being injected into the soil zone (ASGARD, England) to ascertain impacts on pasture and crop plants (West et al, 2008; Smith et al, in press). For the natural sites, botanical, soil gas and gas flux, chemical and microbiological surveys were carried out across CO_2 gas vents. For the controlled injection site, similar surveys were conducted across 2.5 x 2.5 m plots where CO_2 was being injected into the plot centre and the effects were compared with those from control plots. Full details of the sites, methodologies and results are given elsewhere (Beaubien et al, 2008; Krüger et al, 2011; Smith et al, in press; West et al, 2008; Ziogou et al, in press)

Each of these studies is yielding considerable information on the impacts of elevated CO_2 soil gas concentrations on a range of parameters, including botany and soil microbiology, for pasture in different climatic conditions. A comparison of these data can now be made to better understand how local conditions can potentially modify the impact of any CO_2 leak. Broadly, this shows:

1. The impact of CO_2 gas vents on the surface ecosystem at natural sites appears to be highly localised and is dependent on the prevailing extreme CO_2 regime. The spatial variations of

soil CO_2 concentration and fluxes are generally controlled by a complex interplay of factors such as the migration pathway at depth, the physical and chemical properties of the vadose zone, the features and hydrogeology of the near surface deposits etc. Thus, soil gas analyses and flux measurements will be required for baseline characterisation of migration pathways for soil gases and for the design of any near-surface gas geochemistry monitoring program of CO_2 geological storage sites.

2. Results from botanical studies at all the natural sites, where plants have been exposed to high CO_2 soil gas concentrations (up to 80% at 20 cm depth at Florina) for many years, indicate species-specific response to high CO_2 concentrations depending on soil properties, mineralogical composition and temporal and spatial soil CO_2 concentration and flux patterns. Site specific plant 'bioindicators' are also observed for concentrations at ≥35%, such as *Polygonatum arenastrum* at Laacher See. At Florina and Latera, monocotyledonous plants (grasses) become increasingly dominant above 10% CO_2 soil gas concentrations at 20 cm depth and this continues until CO_2 soil gas concentrations reach ~30-40%. Interestingly, this was also observed at ASGARD after the pasture plot had been exposed to elevated CO_2 soil gas concentrations for 24 months. This grass predominance persisted once gassing had stopped.
3. Microbiological analyses at the natural CO_2 vent sites suggest significant changes in the soil microbial community caused by high CO_2 levels in the soil gas. For example, there is a shift in the microbial community composition towards anaerobic and acid tolerant microorganisms as well as an ecosystem adaption to the CO_2 induced soil biogeochemistry. There are also significant effects on metabolic rates with increasing CO_2 soil gas concentrations although this is not reflected in overall bacterial and archaeal cell numbers. However, at ASGARD, after 24 months gassing, total microbial numbers increased when CO_2 soil gas concentrations were between 20-50%. Additionally, at ASGARD where CO_2 soil gas concentrations are <8%, there is little impact on the microbial ecosystem. These differences may be related to long-term adaptation of the microbial ecosystems at the natural sites.

REFERENCES

- Beaubien, S.E. et al, (2008). The impact of a naturally occurring CO_2 gas vent on the shallow ecosystem and soil chemistry of a Mediterranean pasture (Latera, Italy). Int. J. Greenhouse Gas Control 2:373-387.
- Krüger, M. et al, (2011). Effects of elevated CO_2 concentrations on the vegetation and microbial populations at a terrestrial CO_2 vent at Laacher See, Germany. Int. J. Greenhouse Gas Control 5:1093-1098.
- Smith, K. et al, (in press). Environmental impacts of CO_2 leakage: recent results from the ASGARD facility, UK. Energy Procedia.
- West, J. M. et al, (2008). The impact of controlled injection of CO_2 on soil ecosystems and chemistry of an English lowland pasture. Energy Procedia 1:1863-1870.
- Ziogou, F. et al, (in press). Potential environmental impacts of CO_2 leakage from the study of natural analogue sites in Europe. Energy Procedia.

ACKNOWLEDGEMENTS

RISCS is funded by the EC 7th Framework Programme and by industry partners ENEL, I&I, Statoil, Vattenfall AB, E.ON and RWE.