Harmonised CO_2 leak rates in the context of commercial-scale storage

Jennifer J Roberts[1], Linda Stalker[2]

[1] ClimateXChange/University of Strathclyde, Scotland

[2]National Geosequestration Laboratory/CSIRO, Australia

The viability of Carbon Capture and Storage (CCS) depends on the reliable containment of injected CO_2 in the subsurface. The leakage of CO_2 or formation fluids would impact on a number of stakeholders, incurring financial and environmental costs and challenging the public acceptance of the technology. Small amounts of CO_2 leakage could be tolerated without negating the cost-effectiveness of CCS from both climate change mitigation and financial perspectives (if, respectively, CO_2 loss to the surface was no greater than 1% per 1,000 years (IPCC, 2005), or a few percent per year (Zwaan and Gerlagh, 2009). To minimize leakage risk, legislation and guidelines developed for CCS set performance requirements for CCS. For example, the US Department of Energy aims for 99% containment of CO_2 injected for the purpose of geological storage (US DOE, 2014) whereas EU CCS legislation requires CO_2 to remain 'permanently' in the storage formation - and that any CO_2 that leaks from the storage formation must be quantified for reasons of carbon accounting (Dixon et al, 2015). Capability to measure monitor and verify CO_2 leakage is therefore required in case CO_2 leakage is suspected, to inform whether performance requirements are being met and to comply with CCS regulation.

There are a number of potential leak pathways from the intended storage reservoir to surface. For example, injected CO_2 could leak if caprock integrity is bypassed by unsealed geologic faults or transmissive fracture systems in the cap rock, leaking well bores, or poor characterization of the reservoir and overburden characteristics. The rate of leakage, pathway and attenuation on ascent to surface will depend on the seal bypass mechanism itself, as well as other factors such as the site-specific geological properties. It is useful to consider the range in permeability and possible leak rates for these potential CO_2 leak pathways. In the absence of a portfolio of leakage from existing engineered CO_2 stores we must instead learn from industrial and natural analogues, numerical models, and laboratory and field experiments - and there have been a plethora of studies using these different approaches that aim to address this issue. However, few quantitatively assess CO_2 flow rates for a range of leakage scenarios due to challenges regarding high degrees of uncertainty (both geological and operational) (Jones et al., 2015). Additionally, there is no 'standard unit' in which to report CO_2 leak rates, and so leak rates may be reported as flux per unit area, or total CO_2 leakage to surface, in various different units of measurement (various expressions of mass, volume, concentration and time), with different uncertainties. This introduces difficulties when comparing the results of these studies to each other, examining the implications of these leaks with regards to performance requirements for CCS, and communicating these issues with the various relevant stakeholders including regulators. Hence there is a need to harmonise the studied or simulated leak rates and place these in the context of commercial scale CCS sites.

To address these difficulties, in this work we collated a global dataset of the following:

- Rates of degassing at naturally occurring CO_2 seeps via natural and artificial leak pathways (we also consider the flux rates of natural occurrences of methane seeps, and the gas fluxes from poorly sealed natural gas wellbores).
- CO_2 leak rates predicted by geological models for a range of leakage pathways.
- Field scale experiments, which intentionally release CO_2 into the shallow subsurface to simulate CO_2 leaks. These have been particularly valuable for testing methods of measuring and quantifying CO_2, since the CO_2 release rates are "known". We reviewed available information about CO_2 release rate, and the CO_2 leakage to the surface. We also consider why the chosen release rates were selected.
- CO_2 injection rates proposed for proposed commercial-scale CO_2 storage operations and the leak rates permissible - both from climate change and regulatory perspectives. Commercial scale operations are assumed to inject 0.8 - 5 Mt(CO_2)per annum for 40 years, and we consider leakage over three timescales: the injection period, the medium term (100 years) and the long term (1,000 yrs).

We then scrutinise this harmonised dataset to address the following:

- How do the leak rates studied by different approaches (natural analogue, field, simulations) compare to each other? Particularly for the same leak pathways.
- What proportion of CO_2 stored at commercial scale sites would these leak rates represent for the three time frames considered? Would these be acceptable for CO_2 storage requirements? (i.e. < 1% over 1,000 years).
- Using current methods, can we currently adequately quantify CO_2 leakage to a satisfactory degree of certainty?

This work leads onto a discussion about some of the key limitations or uncertainties in the current regulatory requirements concerning 'acceptable' CO_2 leakage, and where these could be better defined. It also highlights some questions regarding what leakage matters, and where (from the intended storage formation? To the shallow subsurface? To the surface?), and from whose perspective (Regulatory? Local environment? Climate change? The Publics?). Finally, this work has revealed where notable knowledge gaps remain, and thus we have identified where should future work focus.

References:

Dixon, T., S. T. McCoy and I. Havercroft (2015). "Legal and Regulatory Developments on CCS." International Journal of Greenhouse Gas Control **40**: 431-448.

IPCC (2005). IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. B. Metz, O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer**:** 442 pp.

Jones, D. G., S. E. Beaubien, J. C. Blackford, E. M. Foekema, J. Lions, C. De Vittor, J. M. West, S. Widdicombe, C. Hauton and A. M. Queirós (2015). "Developments since 2005 in understanding potential environmental impacts of CO2 leakage from geological storage." International Journal of Greenhouse Gas Control 40: 350-377.

US DOE/NETL (2014) Carbon Storage Technology Program Plan. Available at: www.netl.doe.gov/research/coal/carbon-storage/publications [accessed Feb 2016]

Zwaan, B. and R. Gerlagh (2009). "Economics of geological CO2 storage and leakage." Climatic Change 93(3): 285-309.