Bursting Bubbles: Can experiments and analogues help stakeholders and the public visualise risks?

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Abstract.

Laboratory experiments, natural analogues and pilot projects have been fundamental in developing scientific understanding of risk and uncertainty from georesource exploration. International research into CO_2 and CH_4 leakage provide scientific understanding of potential leakage styles, rates and environmental impacts. However, the value of these experiments as a communication tool for stakeholders and the wider publics is often overlooked in the form of visual information and comparisons. Quantifiable lab experiments, measurement of gas at natural springs or controlled release of CO_2 (e.g. QICS project [Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage]) raise awareness and commitment to understanding environmental impacts and geological complexities. Visuals can greatly facilitate communication, and research into public understanding of the subsurface demonstrates that quality and scale of schematics can affect perceived risk. Here, we consider how public perception of subsurface activities could be shaped by relevant and applicable research that shares accessible and visually engaging information. Could images showing bubbles of seeping gas, or showcasing monitoring methods and capabilities, help to contextualise risks and geoscientific concepts, and shape opinions? Can these materials aid dialogue between the wider scientific community, publics and stakeholders? We propose that future projects could improve dialogue through use of context-appropriate visuals to enhance dialogue on risks, impacts and monitoring of subsurface engineering technologies.

Keywords:

Carbon Capture and Storage, leakage, natural analogue, CO_2 seep, CH_4 and hydrocarbon seepage, field experiment, stakeholder perception, science communication, research impact, images, geoenergy, public perception, social license, dialogue, engineering the subsurface.

Introduction

Increased public awareness of geological and industrial processes, combined with increased need for social license, societal support and community engagement, means that now, more than ever, activities at or below ground need to be demonstrably transparent. However, public acceptance and dialogue can be more challenging for emerging, remote, technical, sensitive, uncertain or unfamiliar technologies (Ashworth et al., 2015). For many, such technologies can appear largely “imaginary” (Reiner, 2015); either because the scale is difficult to envisage, projects are far from centres of population, the surface footprint of activities is comparatively small (any underground mine, oil or gas field) or the technology is still at the conceptual stage. To quote Reiner (2015:710) "…it is difficult to engage in a serious public debate over risks or to develop an effective risk communications strategy if there is no actual project on which to present information." For these technologies, activities such as pilot or test projects, lab and field experiments not only test and advance knowledge and capability, they also generate resources valuable for science communication. We propose that research-generated images of processes, concepts, and data could facilitate dialogue with stakeholders on the topic of risk, uncertainty and quantitative impact on a range of subsurface activities.

Recent research efforts into laboratory experiments, natural analogues and field trials or pilot demonstrations could provide invaluable visual resources for facilitating dialogue on leak risk, how leaks manifest, their impact, and monitoring needs. This could be relevant and relatable to stakeholders beyond the immediate CCS or shale gas community.

Discussion

It is a well-known proverb that "a picture speaks a thousand words". Significant efforts have been undertaken to develop materials that have helped to inform a range of stakeholders about CCS concepts (Ashworth et al., 2015). On observing images such as those shown in Figure 1, Ashworth reinforced the powerful nature of such images in illustrating what a leak could look like, and so illuminating the impacts of leakage (Pers. Comm. July, 2017). However, research has found that images alone cannot communicate CCS if the viewer has misconceptions of some aspect of the technology (L'Orange-Seigo et al., 2013).

Figure 1 Measuring CO_2 seepage at sites in Daylesford, Vic. Images from Jen Roberts (L) and Andrew Feitz (R).

Experts or those familiar with geoscience-based industries (e.g. oil, gas, mining or CCS) tend to have become used to employing a developed sense of spatial reasoning and thinking in three-dimensional space. Geological situations can be highly descriptive and visual, combining technical language with gesticulation, and consequently easily misinterpreted by expert and non-expert alike adding to uncertainty. For example, Gibson et al. (2016) found that people experienced in geosciences commonly conceptualise the subsurface in 2- and 3D, but that this was not the case for those with lay geoscience experience. Many individuals with lay geoscience knowledge perceived that fluids moved around the subsurface in rivers, and so porosity and permeability concepts were not known or well understood. Similar gaps in awareness may well be present in concepts of gas flow, storage, migration and leakage to the earth's surface. This could lead to misconceptions around leakage and leak impact, particularly where there are misinterpretations of the process.

It is worth remembering that presentation of 'more' and/or 'better' visuals and data alone risks reiterating the widely-critiqued 'information deficit' model of communication (Bradbury et al, 2011). Data visualisation ought to be considered one part of demonstrating competence, alongside factors such as trust- and relationship-building. For the Tomakomai CCS project in Japan, for example, it is arguably the combination of in-depth data *and* its presentation by local government officials and scientists viewed as trustworthy that has helped the project operators demonstrate credibility in monitoring and management of the storage site (Mabon et al, 2017).

Based on the above, is there a role for laboratory experiments, natural analogues and pilot project in the communication of leakage risks for a range of industries currently?

Natural Analogues

In the absence of any occurrences of human-made gas leakage from geological engineering, geoscientists often use 'natural analogues' or geological examples that can be used to test/validate models or hypotheses regarding expected or predicted behaviour (Figure 1). For example, Italy is a region of natural CO_2 degassing due to a combination of geological factors (Figure 2). A broad range of seepage manifestations are observed to occur, from CO_2 vents (pressurised CO_2 release over a small, focussed, emission point often <1 m^2) to diffuse seeps (distributed seepage across a much wider areas), and springs containing high quantities of CO_2 (Roberts et al, 2011 and references therein). CO_2 seeps in Colorado and Utah in the US, the Eger Rift region of Hungary, Laacher See in Germany, and Victoria, Australia have also been studied (to name a few). A wide range of fluxes are observed at different sites, from the order of kilograms to thousands of tonnes per day. Impact of seepage is affected by more than flux rate: ecosystem, topography and seasonal variations in climate. But, are 'low' natural fluxes actually high from a risk perspective? And how good are we at quantifying leak rates? For that we turn to laboratory experiments and controlled release experiments to improve our characterisation and quantification of leakage.

Figure 2 Examples of CO_2 seepage in Italy. Images Jen Roberts.

Laboratory Experiments

Laboratories can conduct highly controlled experiments to investigate many aspects of gas production/storage and leakage, including preferential leak pathways, chemical tracers for leakage, impacts of leaks on plants and marine life, or how to use bubble size to estimate gas emission. At NGL, we have conducted sand bath experiments (both in a wet and dry state) to explore how accurately we can quantify very small leaks of gas (CO_2 and CH_4). For us, actually imaging the bubbles and relating them to gas migration rates relates directly to observations in controlled release experiments such as that at the QICS site. Results of that subsea test indicated that the bubbles measured only accounted for 15% of the gas injected (Roberts and Stalker, 2017 and references therein, which adds further complexity to how publics may evaluate risks and consequences of potential leakage.

Field experiments of Leakage (aka Controlled Release Experiments)

Certainly in the field of carbon storage research, an emphasis has been placed on demonstrating capability in monitoring and quantifying CO_2 leakage in a range of geological and surface environments. A comprehensive overview of engineered leaks (where controlled CO_2 release into the shallow subsurface simulates seep initiation, to test monitoring tools and understanding of CO_2 flow and fate) can be found in Roberts & Stalker (2017). What that paper notes from the review of 42 experiments at 14 sites around the world (one offshore: QICS), only nine experiments (eight sites) report estimates of total CO_2 leakage to surface. The challenge of quantifying leakage in these settings is still difficult, even though they are controlled. However, these sites do enable better visualisation of the impact of gas leakage to surface e.g. at Ginninderra in ACT, Australia, the impact (hotspot) radius on vegetation can be observed; whereas at QICS, bubbles of gas have been recorded to aid in the estimation of leakage rates. These are all images that can be used to show relative impact, if discussed in appropriate context (Figure 2).

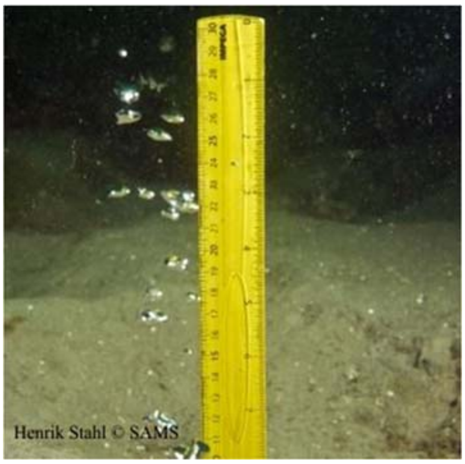

Figure 3 Examples of bubbles escaping the sea bed at the QICS project, Scotland. Images from Henrick Stahl https://www.bgs.ac.uk/qics/gallery.html

Conclusions

By bringing to bear data and physical examples that we can quantify/measure and report, the misalignment often found in messaging relating to gas leakage could be reduced, and perceptions better managed. The use in the QICS project in west Scotland of videos of bubbles on the seabed (Figure 3), a carbonated beverage-making machine, and demonstrations of monitoring equipment all helped members of the public to understand the nature of the CO_2 release and the potential effects of CO_2 on the marine environment (Mabon et al, 2015). However, it is again important to bear in mind that visualisation and data are just one component alongside trust-building and local history and context in shaping publics' responses to subsurface developments.

There are parallels to scholarly thought on the governance of new and emerging technologies, where skills such as anticipatory capability (Stilgoe et al, 2013) – again, ability to envision and imagine 'worst case scenarios' – where visualisations and data may form part of the case for demonstrating competence in monitoring and management and hence allowing new subsurface processes to progress incrementally. Clearly the use of appropriate images can provide some much needed help.

Conflicts of interest

This work has been funded by the host institutions of the authors.

Acknowledgements

The authors would like to thank their host institutions for financial support in the preparation of this extended abstract. LS thanks CSIRO and NGL, JJR thanks the University of Strathclyde, and also the support of UKCCSRC who funded research placements at NGL and LJM thanks Robert Gordon University.

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Biographies

Dr Linda Stalker obtained a BSc. (Hons) in Applied Geology (University of Strathclyde, Scotland) in 1990. Her PhD on petroleum geochemistry and CO_2 generation, was gained at the University of Newcastle-upon-Tyne. In 1994 she joined the University of Oklahoma (USA) on a Department of Energy sponsored post-doctoral study into organosulphur compounds trapped in coals. From 1996 she worked in petroleum E&P at Statoil, in Norway, including 2 years on the Sleipner Field. She joined CSIRO in 2000 as leader in gas geochemistry specialising in analysis and interpretation of carbon and hydrogen isotopes of oil and gases for the petroleum and CBM sectors. She transitioned back to CO_2 related research through activities with the CO2CRC (The Cooperative Research Centre for Greenhouse Gas Technologies) conducting research in the geological storage of CO_2 and in the area of monitoring and verification (tracers). Since 2010, Linda has worked closely with the WA Department of Mines, Industry, Regulation and Safety on the South West Hub CCS project, conducting site characterisation for a possible storage site for CO_2. Linda has been the Science Director of the National Geosequestration Laboratory (NGL) for 7 years and is Group Leader in Exploration Geosciences.

Dr Jennifer Roberts is an interdisciplinary researcher, bridging the physical and social sciences in order to inform how the necessary transition to a low-carbon energy system can be designed and implemented in a way that is acceptable to society, and environmentally and economically effective. Her work in Carbon Capture and Storage focusses on mitigating and detecting CO_2 leakage, and the consequence for site assessment, monitoring and community engagement. For the past 5 years, Jen has worked as a Research Associate at the Department of Civil and Environmental Engineering at the University of Strathclyde, Glasgow (Scotland). From 2013 - 2016 her post was funded by ClimateXChange - Scotland’s Centre of Expertise on Climate Change - which brings together a range of researchers to provide independent advice, research and analysis on climate change and climate change policy in Scotland. Prior to joining Strathclyde in 2013, Jen was a researcher at the Scottish Carbon Capture and Storage group based at the University of Edinburgh, where she obtained her PhD on natural CO_2 seepage. Jen is an active member of the UK Carbon Capture and Storage Research Centre, the Geological Society of London, and the IEAGHG community.

Dr Leslie Mabon is Senior Lecturer and Research Lead in the School of Applied Social Studies at Robert Gordon University in Aberdeen, Scotland. He is an environmental social scientist with a particular interest in some of the more ethically challenging aspects of climate change mitigation and adaptation. Leslie’s work in CCS focuses on balancing stakeholder and citizen views within decision-making processes, and on the role of CCS in a just transition to a low-carbon economy for high-emitting regions. He has undertaken extensive research on the Tomakomai CCS Demonstration project in Japan, and his work related to CCS has been funded by the Regional Studies Association and the UK CCS Research Centre among others. Leslie holds a PhD in Geography from the University of Edinburgh with a focus on consensus-building in environmental governance.