Detecting, tracing and quantifying CO_2 leakage

Carbon dioxide capture and storage (CCS) is a possible mitigation measure to reduce the amount of CO_2 entering the atmosphere where it contributes to climate change, and the ocean where it upsets chemical balances and results in ocean acidification. CCS entails collecting CO_2 at source, transporting it to a suitable site and pumping it into deep geological strata, where it remains locked away.

In order that CCS is accepted by industry, government and wider society there needs to be a high degree of confidence that it is a safe and secure process, through all of its stages. One concern is the slender possibility of a leak, which could be small or large, slow or rapid, potentially resulting in harm to ecosystems, people or property. National and cross-border regulations are increasingly being implemented to ensure any risk is minimised. Alleviating such concerns is pivotal to the acceptance of the technology; central to that acceptance is confidence in monitoring techniques that can detect any leakage, assess its strength and duration, and so allow for remedial actions, if necessary, to be undertaken.

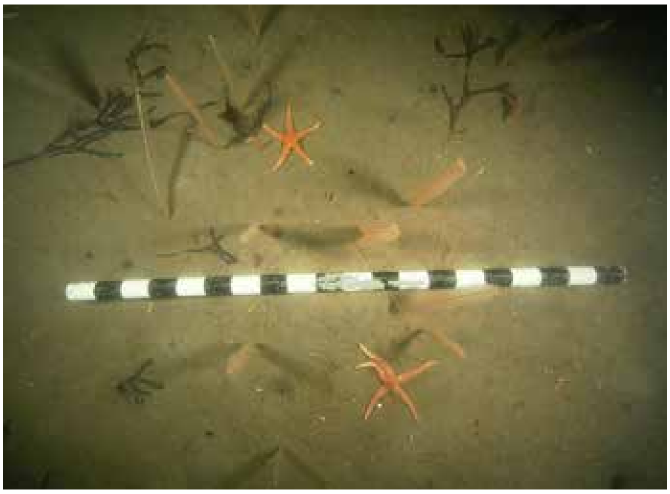
The first two stages of the CCS process are relatively easy to manage from a leakage perspective. Extraction from industrial sources such as power stations and cement works is subject to existing engineering knowledge and governed by national regulations and legislations. Likewise, transport of liquids and gases, whether by pipeline, road or sea, enjoys a long history of development and experience. Under normal circumstances, both stages can be regarded as well categorised and hence 'safe'. The third stage - injecting the captured CO_2 into geological storage and ensuring it stays there - is the least tested part of the CCS process. However, much has already been learnt from the hydrocarbon industry and also from scientific studies at natural seafloor seeps.

What to detect?

Detecting traces of escaping CO_2 and other substances expelled from sub-seabed storage sites is challenging; most proposed storage reservoirs cover large areas deep below the seafloor and may be inaccessible to visual observation. A key aspect of STEMM-CCS research is to examine the applicability of existing or proposed ocean monitoring techniques, and to develop new methods that can provide sufficient coverage in both time and space to be able to detect any release of CO_2 from CCS reservoirs. This advance in understanding will serve to underpin the confidence demanded by legislators, conservation organisations and the wider public.

Biological monitoring

Escaping CO_2 and other substances mobilised from compromised storage reservoirs may introduce nutrients or toxins to the marine environment, affecting organisms on the adjacent seabed or in the water column above. Biological monitoring for detection of leaks relies on having good knowledge of the existing ecology around a storage site, which can act as a baseline against which any changes can be measured. Changes in the biomass, biodiversity and distribution of organisms in the area surrounding a leak are typical observations that can provide useful indicators of leakage, as well as magnitude and duration.



Repeated surveying of seafloor fauna to detect changes is an important component of monitoring at CCS sites. Image courtesy SAMS/QICS.

Changes in seafloor microbial communities within the vicinity of a leak may indicate the presence of natural seep, or they may be a sign of storage-related leaks. Laboratory and natural analogues, in the form of seeps, have provided useful guidance on how biological monitoring techniques might be employed. Physical sampling, the use of remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs) and direct observation by divers are all methods of obtaining the required data pre-, during and post-injection to determine

changes. However, biological monitoring is likely to be restricted to shallower waters because of access challenges, health and safety considerations and expense.

Detection of CO_2 streams

Bubble streams in the water column are an obvious and immediate result of a leak. Such streams may be detected visually via cameras mounted at intervals across a storage site, by cameras mounted on AUVs, ROVs or seabed landers, or by passive acoustic techniques that listen for the sound generated by a bubble stream. However such streams may be small and highly localised and hence difficult to pinpoint. Static cameras and/or acoustic sensors will be especially useful for monitoring changes at identified seep/leak sites.

CO_2 bubbles emitted from the seafloor at the QICS project controlled release experiment site. Image courtesy SAMS/QICS.

Chemical monitoring

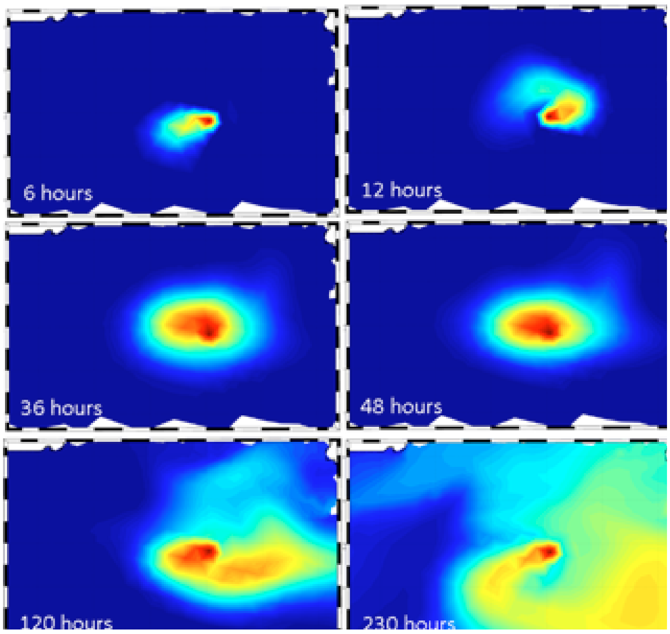
CO_2 streams entering the water column will possess a distinctive chemical 'fingerprint' that is detectable by sensors mounted on static landers and mobile underwater vehicles, or through sampling. Other chemicals, especially hydrocarbons, may be mobilised during the injection and storage of supercritical CO_2 in geological formations. Such substances may migrate through porous strata and have the potential to reach the seafloor and escape into the water column. Detecting these substances may provide early warnings of leakage, but they may also be environmentally harmful in their own right.

Geological and physical monitoring

Monitoring large areas of a storage facility are made possible by seismic /acoustic techniques which can 'map' the extent of a storage reservoir, identify potential leakage routes, detect migration pathways and follow the movement of an injected CO_2 plume. Pressure changes associated with a migrating plume can also be measured and provide an early indicator some distance away from the CO_2 itself: excess pressure may open up new leakage pathways. The installation of sufficient pressure sensors is likely to be expensive and will be a determining factor in choosing such technology. On the seafloor surface, ship-mounted sonar technologies can be used to detect any structures, such as pockmarks, which may be associated with past or present CO_2 emissions - natural or man-made.

Modelling leaks

Efficient and accurate detection and monitoring of a leak depends on sensing technology being suitably located to pick up leakage signals - whether visual, acoustic, physical or chemical. Modelling studies that can project the behaviour of a leak become essential in determining when and where sensors should be located. Artificial tracers that can be detected by sensors may be used to provide data to populate models that predict plume size, growth, direction of movement and lifespan. Suitably parameterised models thus become valuable tools for interpreting data obtained from monitoring and detection activities.



Right: Monitoring the movement of subsurface CO_2 plumes is a key component of CCS site monitoring. Image courtesy PML.

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The STEMM-CCS consortium comprises 12 partners across Europe, coordinated by the National Oceanography Centre, UK. For more information please visit www.stemm-ccs.eu