Establishing baselines for CO_2 storage

Acceptance of CCS as a climate change-related anthropogenic CO_2 reduction strategy depends on high levels of confidence in the integrity of storage sites. Whilst the likelihood of a leak remains low, various national legislations exist that call for dependable detection, monitoring and quantification of leakage, and accurate assessment of any ensuing environmental and climate impacts.

Underpinning the reliability of any monitoring is the requirement to be able to compare new environmental measurements to the natural or 'normal' conditions existing prior to use of a site for CO_2 storage. Establishing such baselines in the marine environment is a difficult but essential component of Environmental Impact Assessments (EIAs).

The marine environment is highly variable

Prevailing marine conditions in a given area can vary considerably over timescales ranging from tidal/daily to seasonal or decadal, but some parameters may vary fairly randomly - for example, anthropogenic noise. Conditions in deeper ocean environments are generally more stable than those in shallower seas, which are prone to more disturbance from sea surface processes such as wave action, temperature fluctuations and chemical balance.

Shallow seas are highly dynamic and variable environments

Most proposed or existing sub-seabed storage locations lie below relatively shallow seas. Further complexity arises from the scale of proposed CO_2 storage sites which may be many hundreds of square kilometres in extent, and show considerable variation across a number of parameters, also any leak is likely to be localised, so the question in establishing baselines may be as much where to measure as what to measure.

Existing data is often limited

Little baseline data exists on real leakage scenarios, except perhaps lessons learned from oil and gas leaks at well sites. Additional information can be gleaned from experimental and observational exercises investigating the impacts of ocean acidification. The QICS project ('Quantifying and monitoring potential ecosystem impacts of geological carbon storage') carried out controlled CO_2 releases from the seabed. This world-first experiment provided much useful information, but was run over a limited duration at a single site. Nevertheless, it helped to crystallise understanding of the essential components necessary for a baseline survey for sub-seabed CO_2 storage sites. It is clear that no single environmental indicator can give the full picture of a potential leak. Multiple measurements of indicators and how they interact are necessary to establish a clear baseline and to underpin future monitoring.

Geophysical baseline

Shelf seas are complex and diverse, often containing naturally-occurring seafloor features such as pockmarks, crevasses or fractures, which might be interpreted as indicators of CO_2 leakage. To distinguish between natural and leak-related features, it is necessary to carry out thorough and repeated geophysical surveys to ensure appropriate spatial coverage and to capture changes over time. Modelling can help predict how CO_2 will behave within a potential reservoir and provide information about the extent of the area that needs to be surveyed for the overall baseline. In the event of a leak, the strata through which CO_2 may pass can play a large part in buffering it, so core samples are required to establish the baseline carbonate content of the local geology.

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Acoustic baseline

Both active and passive acoustic methods can be used to determine leakage traces, such as bubble streams, but it is necessary to establish an acoustic baseline for comparison. Acoustic arrays are required to establish background noise across the changing seasons, including any anthropogenic contributions.

Sources of anthropogenic ocean noise include activities such as shipping and tourism.

Geochemical baseline

Seeps and leaks can fundamentally alter the chemistry of seabed sediments and the water column above but there is no single, simple measure that changes in a linear fashion as CO_2 is released. However, geochemical signatures can provide a useful 'fingerprint' of a leak. Seawater chemistry is complex so a number of measurements are required to establish a baseline; these should include dissolved inorganic carbon, pH, and partial pressure of CO_2 as well as the total alkalinity of the water within a chosen area. There is also a need to gather temperature, oxygen, salinity and pressure data to provide context for any leak-induced changes that may occur. Seawater geochemistry can vary with biological activity and over time, so a thorough suite of measurements is required to capture a true reflection of natural conditions. Sampling will need to be carried on an appropriate scale and may be seasonal, monthly, daily or even hourly. Recent advances in modelling have embraced the natural variability of seawater pH, so can provide reliable background conditions against which leaks can be effectively detected.

Biological baseline

Biology can be affected by changing levels of CO_2, so changes in fauna or functional parameters may be an indicator of CO_2 leakage. Diversity, abundance and behavioural observations over seasonal and monthly periods are required: during periods of high biological activity, daily observations and measurements will be needed to set reliable baselines. Seabed habitat can be quite diverse over short distances, thus adequate sampling is required to encompass this variation, and control sites of similar habitats are required for comparisons and assessments of biological impacts following leakage. Visual observations, backed up by sampling through the seawater-sediment interface are the normal protocols required to acquire baseline and monitoring data.

Routine water sampling methods (left) and advanced autonomous vehicles such as Autosub (middle) can be used to collect environmental data to feed into baseline models. Direct observations and predictive models can be used to monitor the marine environment around CCS storage sites: together they will allow detection of anomalous measurements against expected background values, whilst allowing for natural variations. Right: model data showing annual mean pH at the seafloor.

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