# Influence of $CO_2$ detectability thresholds and remediation response time on surface leakage rate

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## Abstract

Selection of sites for geological storage of $CO_2$ will be done with minimal leakage out of the storage complex (the target formation and any secondary formations with permanent sealing capacity) as one of the main selection criteria. Due to the complexity of the problem, however, it will not be possible to predict with certainty how the storage site will develop, and the ability to monitor the behaviour of the injected $CO_2$ will be crucial for the overall safety. The EU FP7 project RISCS is concerned with fundamental research on impacts on humans and ecosystems of $CO_2$ leaking from geological storage to the surface.

As part of the work in RISCS, modelling and simulation has been performed to determine possible near-surface $CO_2$ leakage rates for a given rate of escape from the storage complex. One of the assumptions in the modelling is that the storage operation is well managed, with regular deep monitoring surveys (seismic, electromagnetic, or other) and with options for quick intervention in case of unwanted behaviour is detected. Deep monitoring of the $CO_2$ injection site is vital if early corrective action shall be feasible. If leakage from a storage complex can be detected early and corrective measures can be employed quickly and effectively, impacts to surface and near-surface ecosystems will be reduced.

This paper investigates how detectability thresholds and remediation response time influences the flux of $CO_2$ at near-surface depth following a leakage from a storage complex.

Screening of a specific candidate storage site will require detailed modelling of the $CO_2$ flow using the available data for this particular site. A number of physical mechanisms influence the behaviour of $CO_2$ as it is injected into a storage site. Geomechanical effects on the storage formation itself will have to be considered, as well as the present and future integrity of wells penetrating the formation. For simulation of potential leakage scenarios a detailed description of the subsurface above the storage complex will be needed.

Rather than to attempt a full treatment of the $CO_2$ migration problem to arrive at possible leakage rates from a specific site, the present paper tries to approach the problem from a different angle. Sufficiently large heterogeneities in the subsurface above the storage complex will cause any upwards migrating $CO_2$ to be forced to move laterally. This will lead to temporary accumulations that will grow in size until the accumulation has spread to a spill point and further upward migration balances the influx to the accumulation. Such accumulations, with a relatively flat upper boundary, can be detected with seismic monitoring

once they reach a certain size. It has been estimated that with geology similar to the Utsira injection case, $CO_2$ accumulations above the storage site of more than 4000 $m^3$ should be detectable (Arts *et al*, 2005). The present paper investigates the following question:

- What magnitude of near-surface vertical $CO_2$-flux can be observed if sufficiently large $CO_2$ accumulations above the storage complex can be detected and the source of the leakage can be remediated?

This leads to two sensitivity studies on how 1) the detectability threshold and 2) the response time for the remediation will influence the results.

A simplified geomodel is assumed for the modelling. It is assumed that the top of the storage complex is located at about 1000 m depth. The $CO_2$ movement in the storage complex itself is not considered, but it is assumed for the sake of the discussion in this paper that at some point in time the stored $CO_2$ reaches a previously unknown weak point in the seal of the storage complex and starts to migrate trough the overlying sediments towards the surface. It is further assumed that the overlying sediments feature sufficient heterogeneity to cause the $CO_2$ to form accumulations. This is modelled by a couple of low-permeability layers. Finally, it is assumed that if such accumulations are detected in the course of regular monitoring operations, the source of the leakage can be identified and remediated.

In the simulations the rate of leakage out of the storage complex is varied between 2 and 600 tonne $CO_2$ per day. For comparison, the estimated $CO_2$ releases as the natural $CO_2$ vents at Horseshoe Lake, California and at Solfatara and Albani Hills, Italia are between 100 and 1500 tonne $CO_2$ per day (Lewici *et al*, 2006). For the largest leakage rates the threshold for detectability is reached within months after the $CO_2$ reach the first low-permeable layer. For the lowest leakage rate the $CO_2$ does not form a large enough accumulation to be detected in the simulated period, due to dissolution in pore water.

For the simulations with the largest leakage from the storage complex and a remediation response time (i.e. time delay between exceeding detection threshold and remediation of leakage source) of one year the rate of $CO_2$ migration into the top 100 m of the model is at maximum 2–3 tonne $CO_2$ per day for a period of about 5 years, and then a decline to near-zero values over a decade. A longer response time leads to a larger amount of $CO_2$ leaked into the sediments above the storage complex and therefore a larger rate in the near-surface region.

**References**

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