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Dossier

CO_2 Capture and Geological Storage: State-of-the-Art
Capture et stockage géologique du CO_2 : état de l'art

CO_2 Storage in Caverns and Mines

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Résumé — Stockage du CO_2 dans les cavernes et les mines — Une option envisagée pour le stockage du CO_2, en plus des procédés classiques (réservoirs déplétés, aquifères salins, charbons), consiste à utiliser les grandes cavités creusées par l'homme, comme les cavernes et les mines. Les cavernes de sel, comme les réservoirs de gaz déplétés et les aquifères, sont utilisées depuis plusieurs dizaines d'années pour stocker le gaz naturel afin de faire face aux cycles quotidiens ou saisonniers de la demande. On trouve aussi des exemples de stockage de gaz naturel dans des mines abandonnées. Ces exemples prouvent que ces sites offrent une alternative au stockage géologique du CO_2, particulièrement lorsque les options classiques sont limitées ou non accessibles au voisinage d'une source de CO_2. En effet, afin de réduire les distances de transport et donc les coûts, il est important que les sites de stockage soient localisés à proximité des points d'émission du CO_2.

Abstract — CO_2 Storage in Caverns and Mines — *In addition to the "conventional" geological storage options (depleted hydrocarbon reservoirs, saline aquifers and unminable coal seams), it has been suggested that CO_2 may also be stored in large man-made cavities such as caverns and mines. It is noted that salt caverns, along with depleted gas reservoirs and aquifers, have been used to store natural gas to meet seasonal cyclic or daily demand increase for several decades. Examples of natural gas storage in abandoned mines can also be found. The proven track record of salt caverns and abandoned mines for natural gas storage suggest that they may offer alternative solutions for geological storage of CO_2, particularly where the conventional storage options (saline aquifers, depleted oil and gas reservoirs and deep unminable coal seams) are limited or not available near a point CO_2 source. In order to reduce the transport distance and thus overall storage cost, geological storage sites should be located as close to the CO_2 emissions points as possible.*

1 SALT CAVERNS

Salt caverns are constructed in naturally occurring thick salt domes, deep underground. Salt formation can be found in almost every part of the world with some exception around the Pacific Rim. Salt caverns are a proven medium for hydrocarbon storage as salt acts as a natural sealant, trapping the natural gas inside the cavern. Salt caverns for gas storage use are formed with a leaching process by pumping hot water to dissolve the salt and removing the resulting brine via a single well, which then serves for gas injection and withdrawal.

The storage capacity for a given cavity volume (several hundreds of thousands to several million cubic meters) is proportional to the maximum operating pressure, which depends on the depth. Salt caverns are typically much smaller than depleted gas reservoirs and aquifers, usually covering only one-hundredth of the acreage taken up by a depleted gas reservoir. As such, they are particularly suited for short-term storage of natural gas because of their high deliverability as well as the ability to quickly switch from injection to withdrawal.

1.1 Long-Term CO_2 Storage

As with other geological storage options, geological screening is important for the selection of a storage site in salt. The region should be free from any tectonic activity and overlying salts and horizontal shale aquitards in place prevent upward migration of CO_2. In general, existing caverns may not be suitable for CO_2 storage due to poor solution practices (Dusseault *et al*., 2002).

Current research on the use of salt domes as an option for CO_2 storage is limited to North America, in particular Canada. Dusseault *et al*. (2002) carried out a detailed feasibility study on the storage of CO_2 in salt caverns proposed in the 100-160 m thick Lotsberg Salt formation, Alberta. This study addressed a number of issues, including a procedure for cavern construction, creep behaviour characterization and filling, and geomechanical modelling of the long-term response of the cavern and overburden strata to salt creep, which is critical for the safe operation of salt caverns for CO_2 storage. The study concluded that "there are no technical obstacles or undue risks yet identified that would mitigate against the use of salt caverns for permanent CO_2 sequestration".

Characteristics of host salt formations dominate cavern configuration design. Two cavern configurations were considered in the study:

– a 100 m diameter sphere, with a total volume of ~ 500 000 m^3 (~ 450 000 m^3 working volume);
– a prolate spheroid measuring 150 m (horizontal axes) × 100 m (vertical axis), giving rise to a total volume of just over 1 000 000 m^3.

Depending on the final sealing pressure, each salt dome can hold up to a maximum 0.5 ~ 1.0 Mt of CO_2. Although the storage capacity of these individual caverns may be small compared to the emissions from large plants, there is the opportunity to create a series of caverns in the extensive salt beds found within the Alberta Basin (Manancourt and Gale, 2004). It has been estimated that (http://www.ptac.org/env/dl/envt0101d.doc) 3500 Mt CO_2 can be potentially stored in salt domes and rock caverns in Alberta and in Saskatchewan, Canada.

1.2 Monitoring and Potential Environment Impact

The rock mass response to salt creep can be monitored using microseismic and surface subsidence surveys for early warning of CO_2 leak through overburden strata. Salt creep will inevitably cause some degree of cavern closure during and after CO_2 filling. If the final filling pressure is significantly lower than the lithostatic stress, overburden strata may become strained over time as a result of slow cavern closure. Creep rate can be reduced by overfill the cavern to close to the lithostatic stress. However, this may cause hydraulic fracturing of the overburden strata. CO_2 may also leak from sealed borehole.

The solution process requires large water reserves (7-9 m^3 /m^3 mined) and produces just as much brine with a salt concentration of 260-310 kg/m^3 (Chabrelie *et al*, 1998). The resulting brine can be used by chlorine and sodium chemistry. If it cannot be utilized, potentially large volumes of extracted brine may be an environmental issue that needs to be addressed.

1.3 Research Needs

The storage of CO_2 in salt caverns is an area which has not been researched in detail. Further research into:

– modelling tools for predicting the long-term response of the rock mass to salt creep and its impact on cavern integrity;
– regional storage capacity and cost estimates is needed.

2 ABANDONED COAL MINES

As with depleted gas reservoirs and salt caverns, CO_2 store in coal mines is inspired by storage projects for natural gas in abandoned coal mines, the oldest of which dates back to 1961. The Leyton coal mines, located near Denver Colorado, were in operation from 1903 until 1950, producing 5.4 Mt sub-bituminous coal from two horizontal seams at 210 m and 225 m depth in the upper Cretaceous Laramin formation. There are two other abandoned mine converted natural gas storage reservoirs, both located in the gassy Hainaut coalfield in southern Belgium.

Piessens and Dusar (2003) have recently carried out a detailed feasibility study on using abandoned coal mines for long-term CO_2 storage, with special reference to a Belgian colliery. CO_2 stored in an abandoned coal mine may exist in one of the three phases: gas phase, in solution in water and adsorbed on remaining coal. The storage capacity has been estimated between 7.5 to 12.5 Mt CO_2, which maybe small, but accounts for approximately 3 to 6% of the emission reduction for Belgium required under the Kyoto agreement.

The technical set-up of an abandoned coal mine storage project is relatively simple. Unlike unminable coal seams, CO_2 induced swelling is not an issue here. In fact, the seams surrounding former mine workings are naturally stimulated and thus high injection rates can be achieved. On the other hand, fractured rock which exists around an abandoned coal mine may provide leakage paths for CO_2 which would not be acceptable as a storage site. Piessens and Dusar (2003) have suggested some special requirements which need to be met in order to obtain a safe and stable reservoir with sufficient capacity. Firstly, the highest level of the mine should be at least 500 m deep, with well-sealed shafts and a tight, mostly dry cap rock. Secondly, in order to prevent mine flooding, the storage pressure should be higher than the hydrostatic pressure of the surrounding strata. This overpressure, typically around 130% of the hydrostatic pressure, in turn places a stringent leak-proof requirement on the top seal of the reservoir and the existing shafts.

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