Title

Comments on Economides and Ehlig-Economides, "Sequestering carbon dioxide in a closed underground volume," SPE 124430, October 2009

Author

Oldenburg, Curt

Publication Date

2010-06-03

Peer reviewed

Comments on Economides and Ehlig-Economides, "Sequestering carbon dioxide in a closed underground volume," SPE 124430, October 2009

Geologic Carbon Sequestration Program
Earth Sciences Division
LBNL

Group summary comments write-up by
Curt Oldenburg, Karsten Pruess,
Jens Birkholzer, and Christine Doughty

October 22, 2009

General Summary

The paper examines the pressure increase resulting from injection of CO_2 into a 1D radial system with closed boundaries. The finding is that unacceptably high pressures are obtained when only 1% or less of the pore volume is occupied by injected CO_2. These results are used to make the general conclusion that large-scale CCS is not feasible.

Comments

The authors present an analysis for closed systems that includes only compressibility to accommodate injected CO_2. The calculations they present are correct for the highly artificial case of a closed system. However, the closed volume conceptual model does not represent real aquifer systems whose caprock has low but non-zero permeability. Tight caprocks have permeabilities of order of microdarcies on regional scales, and there is an extensive body of work that demonstrates that such permeabilities will substantially reduce large-scale pressurization from fluid injection.

Furthermore, the main finding that CO_2 storage in closed reservoirs can utilize only a small fraction of total pore volume is not new. LBNL scientists (Zhou et al., 2008) concluded that, "…less than half a percent of the total pore volume of a closed system would be available for the volumetric storage of CO_2 in a closed system during the injection period." Zhou et al. went on in their paper to examine capacity of realistic systems that are not completely closed (i.e., allow for pressure dissipation and brine migration into and through non-zero permeability seals) and found much higher storage capacity factors.

The need for a closed reservoir, not to mention the difficulty in actually finding any large-scale closed reservoirs, makes the closed-system assumption of the authors highly dubious. On the latter point, no hydrologic system is truly closed over the long time periods (10^2-10^3 year) and large length scales associated with large-scale CCS (1-100 km^2). For example, even if the caprock seal permeability is on the order of a microdarcy (10^{-18} m^2), over the large distances that elevated pressure will propagate during CO_2 injection, brine will be able to flow into the caprock seal in sufficient volume to mitigate pressure rise. On the former point, CO_2 migration, e.g., up dip along a gently sloping monocline, promotes trapping by the mechanisms of dissolution, residual gas trapping, and carbonate mineral formation. As up-dip flow occurs, eventually all of the CO_2 may become trapped even if there is no closure to the structure and the system is open. A second example is that of structural trapping. Specifically, consider the case of free-phase CO_2 buoyantly trapped in an anticline while the aquifer providing the gas-water contact may be entirely open with the reservoir formation actually outcropping at the surface. The point here is that open systems do not necessarily produce CO_2 leakage to the atmosphere, even over very long (>10^3 year) time scales, and can in fact enhance trapping.

For the sake of argument, if we do restrict consideration to hypothetical closed systems, or to a compartmentalized reservoir that can be considered closed on a given time scale, there are methods that can be used to carry out CCS. For example, brine could be produced from the storage reservoir in equal volume to the injected CO_2 to maintain reservoir pressure. Second, the process of brine production with surface dissolution of CO_2 and subsequent brine reinjection could be undertaken, resulting in reduced pressure rise relative to direct CO_2 injection due to increased density of the reinjected CO_2-charged brine. Third, down-hole (in situ) mixing and dissolution of CO_2 with brine could be carried out. The authors do not discuss any kind of process other than direct injection.

To summarize, the authors consider a narrow, and naturally rare, class of reservoirs that are totally closed. They then assume a simple direct injection of CO_2 and find capacity is limited to less than 1% or less of pore volume. The result is not new, and the assumption of a closed reservoir is an end-member case. From this narrow analysis, the authors make sweeping conclusions that are not relevant to the general feasibility of CCS.

Final Comment

The general issue of large-scale pressure changes arising from CO_2 storage in deep saline formations (open or closed) is well recognized in the scientific and technical community, and various studies have been conducted showing magnitude and extent of such changes for simplified systems as well as real sedimentary basins (e.g., Birkholzer et al., 2009; Birkholzer and Zhou, 2009; Nicot et al., 2008; Yamamoto et al., 2009). None of these studies has concluded that CO_2 storage is not feasible. A certain amount of pressure change will cause no harm and can be tolerated. There are various examples of deep formations over-pressured from natural processes.

References

Birkholzer, J.T., Zhou, Q., Tsang, C.F., 2009. Large-scale impact of CO2 storage in deep saline aquifers: a sensitivity study on the pressure response in stratified systems. Int. J. Greenhouse Gas Control 3(2), 181–194.

Birkholzer, J.T., Zhou, Q., 2009. Basin-Scale Hydrogeologic Impacts of CO2 Storage: Capacity and Regulatory Implications, International Journal of Greenhouse Gas Control, published online on 8/8/2009, DOI: 10.1016/j.ijggc.2009.07.002.

Nicot, J.P., 2008. Evaluation of large-scale carbon storage on fresh-water section of aquifers: A Texas study. Int. J. Greenhouse Gas Control 2(4), 582–593.

Yamamoto, H., Zhang, K., Karasaki, K., Marui, A., Uehara, H., Nishikawa, N., 2009. Numerical investigation concerning the impact of CO2 geologic storage on regional groundwater flow. Int. J. Greenhouse Gas Control, 3(5), 586-599.

Zhou, Q., Birkholzer, J.T., Tsang, C.F., Rutqvist, J., 2008. A method for quick assessment of CO_2 storage capacity in closed and semi-closed saline formations. Int. J. Greenhouse Gas Control 2(4), 626–639.

Acknowledgment

This work was supported by the Assistant Secretary for Fossil Energy, Office of Sequestration, Hydrogen, and Clean Coal Fuels, through the National Energy Technology Laboratory, U.S. Department of Energy, under Contract No. DE-AC02-05CH11231.