Geologic Carbon Dioxide Sequestration Column Height Sensitivity Analysis

Buursink, Marc L.[*1]; Covault, Jacob A.[1]; Jahediesfanjani, Hossein [1] (1) US Geological Survey, Reston, VA.

The influence of seal and reservoir parameters on maximum column height of buoyantly trapped carbon dioxide (CO_2) is essential for developing a quantitative approach to sequestration. Geologic sequestration entails secure and long-term storage of supercritical CO_2 in deep saline aquifers or brine formations. Therefore, predicting the maximum sustainable column height an overlying sealing formation can withstand without allowing CO_2 to leak is important to assessing geologic storage. Moreover, without sufficient column height, CO_2 sequestration projects may not be viable due to regulatory and economic constraints.

The maximum column height of any buoyant non-wetting fluid phase may be computed using the Jurin height rule with the Young-Laplace equation. Seal and reservoir parameters included in these relations are: (a) difference in density between formation water and supercritical CO_2; (b) contact angle between formation water and CO_2; (c) interfacial tension (IFT) between formation water and CO_2; and (d) pore throat size of the cap-rock or overlying shale seal. Multiple studies examining the natural ranges of these seal and reservoir parameters at in-situ storage conditions have been published after sequestration experiments. We perform a sensitivity analysis by varying each parameter independently over the natural range. Maximum column height is inversely proportional to CO_2 density and pore throat size, and we find that knowing these parameters is important. For the natural range of CO_2 densities (450 to 900 kg/m^3) and keeping all other parameters constant (40° contact angle, 0.035 N/m IFT, and 50 nm pore diameter), maximum column height ranges about two-fold. As CO_2 density decreases to a fraction of the formation brine density, column height does not decrease below 380 m. For the natural range of cap-rock pore diameters (5 to 140 nm), maximum column height ranges ten-fold, and does not decrease below 300 m at the largest pore size. Therefore, maximum column height increases significantly if either pore size decreases or CO_2 density increases over their natural ranges. CO_2 density is a factor of basin geothermal and pressure gradients. Furthermore in our sensitivity analysis, maximum column height is directly proportional to IFT and contact angle. For the natural range of IFT (0.015 to 0.05 Nm) and keeping all other parameters constant (725 kg/m^3 CO_2 density, 0.8 contact angle cosine, and 50 nm pore diameter), column height ranges one-fold and does not decrease below 300 m at the lowest IFT. In the sensitivity analysis for the natural range of contact angle (25 to 60°), maximum column height ranges about a third and does not decrease below 450 m at the lowest contact angle. Ultimately, our calculated column heights are often greater than available storage formation thickness (20 to 500 feet) reported for horizontal (typically not dipping) beds in sequestration literature.