XVIII International Conference on Water Resources
CMWR 2010
J. Carrera (Ed)
CIMNE, Barcelona 2010

BASIN-SCALE CO_2 STORAGE CAPACITY ESTIMATES FROM FLUID DYNAMICS

Michael L. Szulczewski[*], Christopher W. MacMinn[†] and R. Juanes[*]

[*] Massachusetts Institute of Technology (MIT)
Department of Civil and Environmental Engineering
77 Massachusetts Ave, Bldg 48, Cambridge, MA 02139, USA
e-mail: juanes@mit.edu, mszulcz@mit.edu, web page: http://juanesgroup.mit.edu

[†] Massachusetts Institute of Technology (MIT)
Department of Mechanical Engineering
77 Massachusetts Ave, Bldg 48, Cambridge, MA 02139, USA
e-mail: cmac@mit.edu, web page: http://juanesgroup.mit.edu

Summary. We study a sharp-interface mathematical model for the post-injection migration of a plume of CO2 in a deep saline aquifer under the influence of natural groundwater flow, aquifer slope, gravity override, and capillary trapping. The model leads to a nonlinear advection-diffusion equation, where the diffusive term describes the upward spreading of the CO2 against the caprock. We find that the advective terms dominate the flow dynamics even for moderate gravity override. We solve the model analytically in the hyperbolic limit, accounting rigorously for the injection period—using the true end-of-injection plume shape as an initial condition. We extend the model by incorporating the effect of CO2 dissolution into the brine, which—we find—is dominated by convective mixing. This mechanism enters the model as a nonlinear sink term. From a linear stability analysis, we propose a simple estimate of the convective dissolution flux. We then obtain semi-analytic estimates of the maximum plume migration distance and migration time for complete trapping. Our analytical model can be used to estimate the storage capacity (from capillary and dissolution trapping) at the geologic basin scale, and we apply the model to various target formations in the United States.

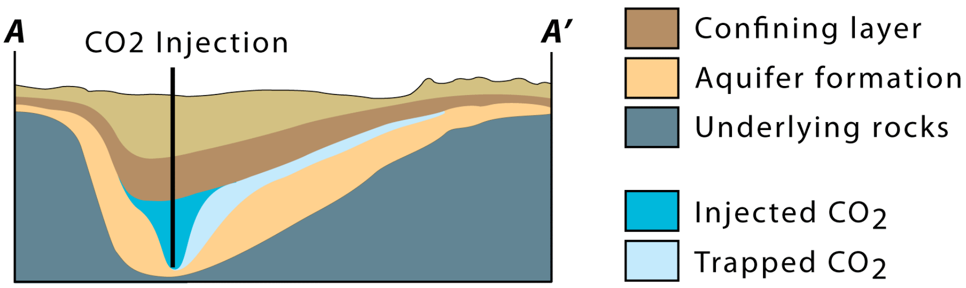

Figure 1: Schematic of the migration of a CO2 plume at the geologic basin scale. During injection, the CO2 forms a plume that is subject to gravity override. During the post-injection period, the CO2 migrates updip and also driven by regional groundwater flow. At the back end of the plume, where water displaces CO2, the plume leaves a wake or residual CO2 due to capillary trapping. At the bottom of the moving plume, CO2 dissolves into the brine—a process dominated by convective mixing. These two mechanisms—capillary trapping and convective dissolution—reduce the size of the mobile plume as it migrates. We present an analytical model that predicts migration distance and time for complete trapping, and we use it to estimate CO2 storage capacity at the basin scale.