Carbon geological sequestration: effects of parameter uncertainty on fluid overpressure and CO_2 leakage

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Abstract. Carbon Capture and Sequestration (CCS) is a feasible approach for the reduction of concentrations of carbon dioxide (CO_2) in the atmosphere. Deep saline aquifers are possible sites for long-term CO_2 storage. CCS involves the injection of CO_2 in supercritical state into deep saline aquifers. Supercritical CO_2 is less dense and less viscous than brine, which causes gravity override. If the injected CO_2 finds a potential pathway that leads back to the surface, it may affect adversely shallow groundwater resource or even land surface. Besides, creation of these pathways may be favored due to the increased pore pressure and the resulting effective stress reduction during the injection of CO_2 into the formation. The characterization of a potential site for CCS is typically a difficult task, given the uncertainties associated with the site properties of interest. Therefore, assessing the uncertainty of these parameters and their influence on the leakage of CO_2 and maximum fluid overpressure produced by carbon injection is essential before the implementation of this technology. In this study, the variable parameters that are studied are: porosity and permeability of injected aquifers, cap rock permeability, as well as the location, size and permeability of carbon leakage pathways trough the sealing layers. Each of these parameters is associated to a statistical probability distribution function prescribed to represents typical ranges of variability. A semi-analytical solution is used to simulate the injection of CO_2 into a hypothetical deep saline aquifer overlain by a sequence of aquitards and aquifers. Different injection scenarios are considered, which differ from one another depending on CO_2 injection rates. A Monte Carlo method is applied to model the influence of the uncertain parameters on the sensitivity and performance of: (i) spatial distribution of the CO_2 plume; (ii) amount of CO_2 that migrates into overlying formations in relation to the total mass of injected CO_2; (iii) maximum fluid overpressure produced by carbon injection. Results are presented in terms of sample cumulative distribution functions, which can be used to estimate: the probability of leaked mass to be exceeding predefined threshold values; and the probability of fissuring that may undermine the sealing properties of the cap rock.

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