The Hong Kong Polytechnic University
Department of Applied Mathematics

Colloquium

Model Complexity and Simulation Approaches for Geological Sequestration of Carbon Dioxide

by

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If the relentless increase in anthropogenic greenhouse gas emissions is to be mitigated, engineered solutions must be deployed on a very large scale. The most important anthropogenic greenhouse gas is carbon dioxide (CO_2). While a number of technologies can lead to emission reductions, the only currently available technology that allows continued use of fossil fuels while reducing CO_2 emissions is Carbon Capture and Storage, or CCS. The idea is to capture the CO_2 at large stationary sources like power plants, and to inject the captured CO_2 into deep geological formations. For this to be a feasible solution, the long-term fate of the injected fluid needs to be understood, and the behavior of the overall subsurface system must be simulated. This includes estimates of the amount of fluid likely to leak upward into shallow drinking-water zones or ultimately back to the atmosphere. In places like North America, where more than a century of oil and gas drilling has left millions of abandoned wells, leakage along old wells is an important concern, and the associated risk of leakage needs to be quantified. The mathematical description of this overall system involves extreme spatial and temporal scales, with the relevant physical and chemical processes leading to a potentially large set of coupled nonlinear partial differential equations. In order to provide tractable solutions, we have developed a series of successively simplified models that capture the dominant physics of the system while being extremely efficient. This allows for large numbers of Monte Carlo simulations to be performed as part of a risk analysis. Large numbers of simulations are required because of the high uncertainty in the properties of leaky wells. When coupled with experiments to estimate the statistics of the properties of old wells, a quantitative risk assessment for leakage can be achieved. For an application in the Alberta Basin of western Canada, the results show a low risk of significant leakage along old wells over 50 years of CO_2 injection.

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