RECENT ADVANCES IN NUCLEAR WASTE ISOLATION THROUGH SIMULATIONS WITH THE TOUGH CODES

Guest Editor

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The safe geologic disposal of high-level radioactive waste is a challenge of great importance for many countries. The fundamental requirement is to protect public health and the environment from radiation emitted by waste for tens to hundreds of thousands of years. The safety of a geologic repository depends on the long-term performance of natural and engineered barriers, which together prevent or delay the transport of radionuclides to where the public could eventually be exposed. The evaluation of repository safety—often referred to as performance assessment—is not a simple matter, primarily because the processes involved are very complex and because the safety assessment covers long time periods and large spatial extents.

Numerical simulations play a prominent role in the performance assessment of geologic repositories. They are indispensable tools for advancing our fundamental understanding of relevant processes, for characterizing a geological site and evaluating respective data, for planning laboratory and in situ experiments and analyzing the measurements, and for conducting predictive simulations in support of performance assessment including the assessment of related uncertainties. The complexity of the processes involved in predicting the behavior of engineered components (e.g., the containers and buffer materials) as well as the evolution of the geologic environment surrounding emplacement tunnels call for sophisticated modeling codes capable of handling the strong nonlinearities; the interactions of coupled hydrological, thermal, chemical, mechanical, and biological processes; and the multiscale heterogeneities inherent in such systems. With all the advances that have been made in improving our understanding, numerical modeling of these complex processes still remains a challenging task.

The first four papers in this special issue of *Nuclear Technology* are illustrative of the enormous potential of numerical simulators in the context of nuclear waste isolation. These papers describe recent developments and applications of one particular set of codes, the TOUGH2 family of codes (available on the Internet at http://esd.lbl.gov/TOUGH2), a suite of general-purpose numerical simulators for multidimensional fluid and heat flows in porous and fractured geologic systems. The papers selected for this issue are a subset of presentations given at the TOUGH Symposium 2006, which brought together developers and users of the TOUGH codes at the Lawrence Berkeley National Laboratory in Berkeley, California, for three days in May 2006 (the TOUGH Symposium 2006 Web site is available on the Internet at http://esd.lbl.gov/TOUGHsymposium). The papers presented at this symposium covered a wide range of topics, including nuclear waste isolation, vadose zone hydrology, environmental engineering, hydrocarbon and gas hydrate recovery, carbon sequestration, mining engineering, and geothermal reservoir engineering. This special issue contains revised and expanded versions of four selected papers from the TOUGH Symposium 2006, focusing on issues related to nuclear waste isolation and the assessment of engineered/geologic barriers to radionuclide migration.

The first paper, by Senger et al., utilizes the two-phase capabilities of TOUGH2 to investigate the migration of gas generated from corrosion or degradation of waste material through the engineered barrier into the geosphere. Data measured in an in situ test conducted at the Grimsel Test Site in Switzerland are successfully interpreted with the numerical model. Another example for successful integration of testing and modeling is described in the paper by Kowalsky et al., where thermal, hydrological, and geophysical data obtained in a large-scale in situ heater test conducted at Yucca Mountain, Nevada, have been jointly inverted using iTOUGH2, a code that provides inverse modeling capabilities for TOUGH2. The next two papers describe new developments and applications using TOUGHREACT, a simulator that integrates reactive chemical transport to the TOUGH2 framework. Zhang et al. present the implementation of a new activity model for highly concentrated solutions and apply this model to predict the evaporative drying and salt precipitation processes expected within and near waste emplacement tunnels at Yucca Mountain. Kiryukhin et al. use TOUGHREACT to model the chemical interactions between deep aquifer rocks and injected fluids, and evaluate their dependence on pressure and temperature conditions. These processes are relevant for the safety assessment of sites for the deep injection of liquid radioactive wastes in Russia.

As guest editor, I would like to thank the authors for interesting contributions and the reviewers for thoughtful and constructive review comments. The papers selected for this special issue reflect the continuing trend toward increased sophistication of the capabilities and applications of the TOUGH2 family of codes. On behalf of the authors and myself, I also express my sincere appreciation to Nicholas Tsoulfanidis for providing the opportunity to publish these papers together in a special issue of *Nuclear Technology*.