Sequential Thermo-Hydraulic Modeling of Variably Saturated Flow in High-Level Radioactive Waste Repository

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Introduction

The most long-lived radioactive wastes must be managed in a safe way for human health and for the environment. That is the raison why the French agency for the management of radioactive waste (ANDRA) is engaged to study the feasibility of a deep geological repository in the low permeable Callovo-Oxfordian clay [1].

The long-term safety performance of such a repository is indirectly related to the evolution of heat and water saturation in the repository and in the host rock. For instance, the corrosion of metals and gas generation, which can affect repository safety are dependent on water saturation (or vapor) and temperature within the repository system [2].

In the perspective of taking into account the gas generation in the system, we developed a sequential model to predict the coupled thermo-hydraulic processes at a cell-scale radioactive waste repository for different operating phases.

Modeling processes and results

The model axisymmetric geometry is represented by a vertical cross section taken through the disposal cell (Figure 1). A common form of the Richard's equation is used for variably saturated flow and a one-equation model is developed for heat transfer in the clay rock.

The simulation considers three different periods: I. A 5-year period after instantaneous storage gallery digging with a ventilation all along the disposal cell, II. A 5-year period begins after setting up the waste containers with generating a variable temperature, III. A 120-year period that begins immediately after establishing clay and concrete plugs into the disposal cell head.

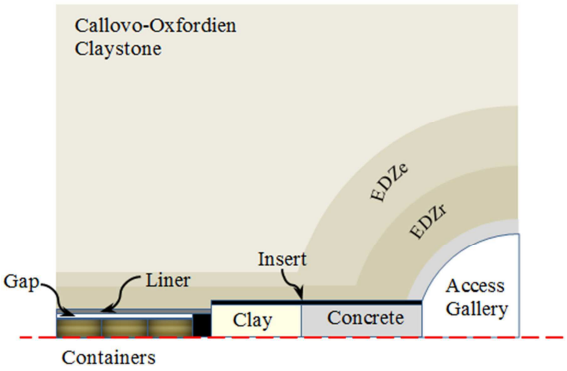

Figure 1: Schematic of the cell-scale repository

The fully coupled partial differential equations have been solved using COMSOL Multiphysics® with appropriated initial and boundary conditions for each operating periods. The results for the saturation in the fractured zone are plotted in Figure 2 along the *x*-axis. During the first stage of the operating phases, disposal cell is ventilated and the clay rock is progressively desaturated. In the second and third stages, as soon as the waste containers are emplaced and the disposal cell head is sealed, resaturation of the clay rock starts. The results show a significant impact of the radiation heat transfer on the temperature profiles. The proposed model that captures quite well the transition between different operating stages can be then used to predict the gas generation in the waste repository.

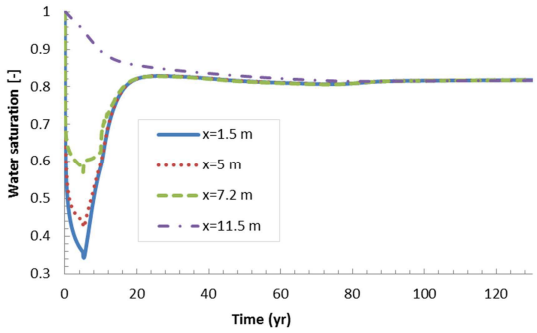

Figure 2: Kinetic of water saturation during the different operating phases in fractured clay zone

References

[1] Andra, Dossier 2005 – Synthesis: Evaluation of the feasibility of a geological repository in an argillaceous formation (2005).

[2] C.P. Enssle, J. Croisé, A. Poller, G. Mayer, and J. Wendling. Full scale 3D-modelling of the coupled gas migration and heat dissipation in a planned repository for radioactive waste in the Callovo-Oxfordian clay. Physics and Chemistry of the Earth. **36**, 1754-1769, (2012).