Geophysical Research Abstracts
Vol. 20, EGU2018-10035, 2018
EGU General Assembly 2018

Diffusive Transport Modelling of Corrosion Agents through the Engineered Barrier System in the Canadian Deep Geological Repository for Used Nuclear Fuel

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Canada's plan for the long-term management of used nuclear fuel is a deep geological repository (DGR), developed by the Nuclear Waste Management Organization (NWMO). The DGR will rely on an engineered barrier system (EBS) to protect people and the environment. To contain and isolate radionuclides, the EBS will be constructed within a low permeability host rock and the used fuel containers (UFCs), made up of an inner steel container surrounded by a copper layer, will be surrounded by a bentonite clay buffer. The clay buffer is important for heat dissipation, as well as, for protecting the UFC from corrosion. For example, sulphide, which may be present in the surrounding pore water, could be transported into the DGR resulting in the microbiologically influence corrosion (MIC) of the copper layer. In order to understand sulphide transport and to aid in the EBS design, a numerical model was developed capable of simulating the diffusion of corrosive dissolved compounds through the bentonite buffer under thermal and variably-saturated conditions. The transport modelling of corrosive compounds provides information that can assist in the establishment of a MIC allowance for the UFC and the developed model can be applied to a variety of scoping scenarios.

The simulations performed consider the geometry of the current NWMO EBS design, as well as, predicted repository environmental conditions for a generic repository site. Results show that corrosion from sulphide diffusion is not uniform over the container, as would be predicted using one-dimensional (1D) calculations. In all cases, 3D modelling predicts zones of higher corrosion at the hemi-spherical end caps due to geometry effects. This results from the larger surface area of the placement room relative to the UFC causing sulphide diffusing inwards to concentrate on the UFC end caps. This work therefore highlights the need for using 3D modelling to predict MIC.

Simulations were also performed under varying repository environments. For example, the repository temperature, as well as, subsurface saturation will change with time due to groundwater conditions and the heat coming from the used fuel containers. Due to the changing nature of the DGR, the model was developed for various DGR conditions: 1) isothermal and fully saturated 2) non-isothermal and fully saturated, and 3) isothermal and variably saturated. For the isothermal, fully saturated condition, the estimated corrosion rate was 0.76 nm/year/ppm of sulphide, based on a constant 1 ppm concentration boundary. The model also predicted that the time required for sulphide to saturate the bentonite was approximately 2,000 years. Consideration of thermal effects resulted in a steady state corrosion rate of 0.53 nm/year/ppm sulphide. Finally, the variably saturated module predicted full water saturation of the DGR at approximately 2,000 years with the first saturated pathways to the UFC surface appearing around 200 years.