Numerical Simulations of Radionuclide Transport Through Clay and Confining Units in a Geological Repository Using COMSOL

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Abstract

Introduction: The sectoral plan that defines the procedure and criteria of site selection for deep geological repositories for all categories of waste (high-level and low- and intermediate-level waste) in Switzerland started in 2008 and will last for about ten years. ENSI (Swiss Nuclear Safety Inspectorate) is in charge of reviewing the proposals and safety assessments for geological repositories submitted by the Swiss implementer Nagra (National Cooperative for the Disposal of Radioactive Waste). In order to review Nagra's safety analyses, ENSI performs independent calculations using COMSOL and other codes. Benchmark calculations have been conducted and the results of four different codes have been compared earlier (see Sentis et al., 2009). In this report selected results of calculations conducted for low- and intermediate-level waste repositories using COMSOL will be presented. Use of COMSOL Multiphysics: The modeling of the advective-diffusive transport of safety relevant radionuclides through the host rock and confining units was conducted in COMSOL using the "Darcy's Law" and "Solute Transport" interfaces. By means of biosphere transfer coefficients the resulting flux of radionuclides was converted into annual doses. The 2D model consisted of the repository cavern (including a surrounding buffer), the host rock and in some cases confining units with different hydrogeological properties. A hydraulic gradient of 1m/m was assumed in vertical direction, whereas 0 m/m was assumed horizontally. The lateral boundaries were constrained to "no flow" conditions, as the modeled domain (gray area in Figure 1) is enclosed by symmetry axes between neighboring caverns (see Figure 1). Based on this model and on a conceptualization of different geological architectures transient radionuclide fluxes and doses over very long time spans (i.e. up to 1e7 years) were calculated. Results: Figure 2 shows results of the calculations for the annual doses of the nuclides I-129, Se-79 and Cl-36 for the model in Figure 1. In this model of a generic repository the radionuclides were transported through 20 m of clay and then directly discharged into the biosphere, which represents a conservative approach because it neglects the retention capacity of the confining rocks. Several realistic scenarios with larger transport pathways were also calculated. Conclusion: Different model set-ups (including confining geological units with different material properties) were implemented and solved using COMSOL's "Darcy's Law" and "Solute Transport" interfaces to review the analysis performed by the Nagra. COMSOL is a user-friendly, robust and fast tool that is being applied successfully by ENSI to review safety assessments and will be applied for further studies as well. ENSI is currently considering the use of COMSOL to calculate two-phase flow and to model discrete fault zones with

a significantly larger advective transport component compared to the intact host rock.

Reference

1. M. L. Sentis et al., Benchmark Calculations with COMSOL of the Transport of Radionuclides through Clay and Bentonite Barriers in a Geological Repository, Proceedings of the COMSOL Conference 2009 Milan (2009).

Figures used in the abstract

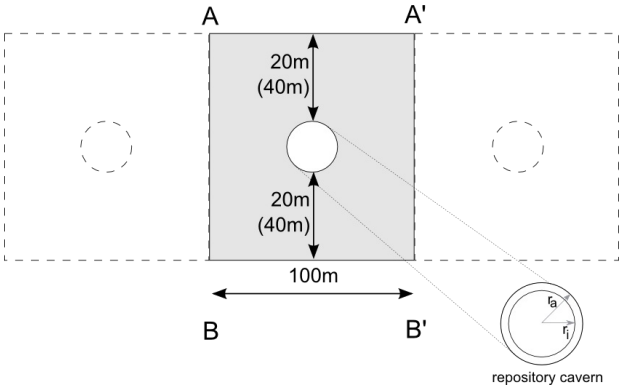

Figure 1: Sample sketch of model geometry (in this case ri is 4.95 m and ra 5.95 m).

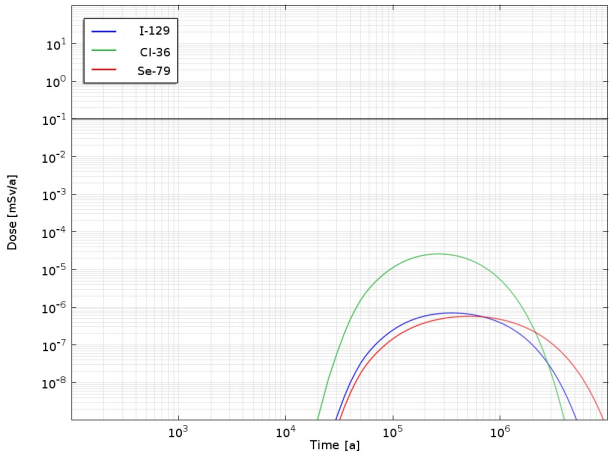

Figure 2: Resulting annual doses for a generic model in which the radionuclides are transported through 20 m of clay (conservative assumption).