Development of a COMSOL Application for the Efficient Evaluation of an Engineered Barrier System

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Abstract

Radioactive waste disposal systems typically comprise a series of barriers that aim at protecting the environment and human health. The presence of several barriers enhances confidence that the waste will be adequately contained. In deep geological disposal systems, the barriers include the natural geological barrier and the engineered barrier system (EBS).

The efficiency of the EBS and the geological barrier is often tested through complex numerical models. These models serve to evaluate the response of the barrier under different sensitivity scenarios. One important factor to be evaluated is the groundwater flow crossing the barriers under different scenarios, which often consist in changes in the hydraulic properties of the different materials or changes in the waste compartment location.

The present work shows an example of a COMSOL application set up to allow such sensitivity analyses. The model behind the app contains a hydrogeological groundwater flow model of a specific vault (1BMA) for intermediate level radioactive waste disposal SKB, 2014) operated by the Swedish nuclear waste management company (SKB). The vault geometry is shown in Figure 1.

The numerical model computes the groundwater flow and the residence time of groundwater within the vault. The numerical models have been implemented in COMSOL Multiphysics software using the Darcy's law and the solute transport (Subsurface Flow Module). The main results are the values of flow entering a set of control volumes in the vault and waste. The residence time is calculated by numerically computing, at the vault scale, Goode´s equation for the mean groundwater age (Goode et al, 1996). Residence time is defined as the spatial distribution of the mean groundwater age taking into account advection, diffusion and dispersion processes.

The application allows the user to change permeability, porosity and effective diffusion of the different engineering materials and in the boundary conditions of the model (Figure 2).

Once the new material properties have been defined, the user can compute the groundwater flow field (Darcy's law physics) and the residence time of groundwater in the vaults (Solute transport physics). The solution of the simulation can be analyzed through a set of predefined plots and

tables.

In conclusion, the COMSOL Application Builder allows to create tools for the necessary sensitivity analysis in the nuclear waste management studies. The application allows design engineers to perform different analysis and use these results to make decisions.

Reference

COMSOL, 2015. COMSOL Multiphysics. COMSOL AB, 2015.

Goode D J, 1996. Direct simulation of groundwater age. Water resources research, vol 32. N.12, pages 289-296.

SKB, 2014. Initial state report for the safety assessment SR-PSU. Tr-14-10. Svensk Kärnbränslehantering AB.

Figures used in the abstract

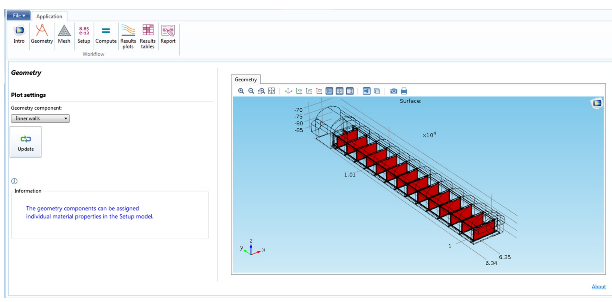

Figure 1: Visualization of the vault geometry and components in the COMSOL application.

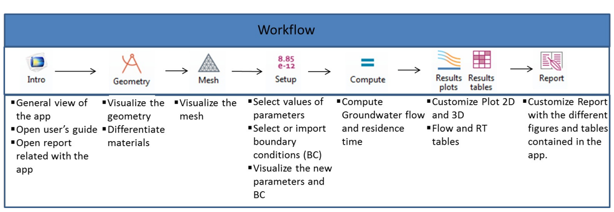

Figure 2: Application workflow and list of the main application capabilities.

Figure 3

Figure 4