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Radionuclide transport during glacial cycles: Comparison of two different approaches for handling flow transients

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We investigate the effect of future, transient ice sheet movement and permafrost development on transport of radionuclides from a proposed repository site in Sweden using numerical groundwater flow and radionuclide transport modelling. Specifically, two different transport approaches are compared. Both approaches utilize simulations of the groundwater flow field of several future climate regimes. The groundwater flow modelling comprises a transient simulation of glacial advance and retreat. The different climate regimes are identified as steady-state snap-shots in time during the glacial advance/retreat and are used as time epochs with constant characteristics in the subsequent transport modelling. The first transport approach uses steady-state particle trajectories representing temperate climate conditions, but modifies the transport velocity along the trajectories according to the flow ratio at repository depth between the other climate regimes and the temperate regime. The second approach uses the time epochs in a pseudo-transient fashion, where particle tracking is performed in each individual flow field representing a given time epoch.

The transport code MARFA (Painter and Mancillas, 2009) is used for both cases. MARFA uses a particle-based Monte Carlo method to simulate the transport of radionuclides in a sparsely fractured geological medium. The algorithm uses non-interacting particles to represent packets of radionuclide mass. These particles are moved through the system according to rules that mimic the underlying physical transport and retention processes. The physical processes represented in MARFA include advection, longitudinal dispersion, Fickian diffusion into an infinite or finite rock matrix, equilibrium sorption, decay, and in-growth. The set of times required for particles to pass through the geological barrier are used to reconstruct discharge rates.

Two different climate sequences are analyzed. First, a simplified sequence consisting of Temperate, Permafrost, Glacial advance and Glacial maximum conditions is assessed in order to understand if the two different transport approaches yield significantly different breakthrough characteristics. Second, a sequence implying a repetition of full glacial cycles of approximately 120,000 years each resulting in a simulation time of 1 million years is considered. The second sequence represents conditions relevant for real safety assessment applications.

Results indicate that the transport approach using fixed trajectories tends to significantly over predict breakthrough during permafrost conditions relative to the pseudo-transient approach. However, the fixed trajectory approach may also slightly under predict breakthrough for other climate regimes and hence be non-conservative. The major difference between the two approaches is related to discharge location characteristics. The fixed trajectory approach yields discharge locations constant in time whereas the pseudo-transient approach is characterized by both distinct discharge centres associated with the different climate regimes as well as a diffuse discharge between these centres.

Reference:

Painter, S. Mancillas, J, 2009. MARFA version 3.2.2 user′s manual: migration analysis of radionuclides in the far field, SKB R-09-56. Available at www.skb.se.