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A sensitivity and probability analysis of the safety of the deep geological nuclear waste repository deposited in a crystalline rock

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A deep geological waste repository shall be designed so as to ensure the safety for thousands of years. The safety concept of a repository system is substantially affected by a type of a host rock. In a rock salt, the safety concept relies on a very slow migration of radionuclides in an almost free water environment and on a gradual self-sealing of excavations due to creep of the salt. In a clay, the safety relies on a very slow diffusion transport due to a highly impermeable rock and also gradual self-sealing of excavations due to creep of the clay. In a crystalline rock, however, the safety that might be strongly affected by advection through fractures in the host rock relies also on long-term performance of engineered barriers, primarily on corrosion resistant canisters.

The aim of this paper is to present the sensitivity and probability analysis of a model of the Czech safety concept of deep geological repository The repository is, in this model, considered as a connected system of engineered and natural barriers. The fuel matrix consisting of uranium dioxide crystals in which are incorporated minor actinides and fission products forms the first barrier. The nuclear waste is supposed to be enclosed in steel based canisters which are placed in vertical boreholes at depth of ~ 500 m. The space between canisters and host crystalline rock is backfilled with compacted bentonite which forms the last engineered barrier.

After failure of canisters, instant release fraction of radionuclides located mainly between spent fuel cladding and uranium matrix can release immediately. Radionuclides fixed in the uranium dioxide matrix will be released from the matrix congruently with the relative rate of dissolution of the matrix, which is considered to be very low, 1•10 8 a-1 approximatelly. Released radionuclides will diffuse through the layer of compacted bentonite and rock (granite) matrix and will reach flowing water in granite rock fractures.

The following processes influencing the migration rate of radionuclides from the repository to the biosphere are taken into account in the tested conceptual model: the water chemistry, the solubility, diffusive and sorption properties of radionuclides, and the water flow rate in the fractures. For the analysis performed, the repository system was simplified into a system of compartments. To account for various types of uncertainty, e.g. incompleteness associated with the reduction of complex heterogeneous system to a compartment model, randomness of rock fractures; the values of some model parameters were considered as uncertain. Parameters uncertainties were modelled via probability density functions which were assigned by expert judgment. The sensitivity analysis was performed using a variance based method which decomposes a total variance of a model output into contributions from each parameter. The calculation of the variance decomposition was based on a Monte Carlo simulation with Sobol'quasi-random sequences. The results of the analysis are presented for a set of critical radionuclides, in particular 14C, 36Cl, 79Se, 129I and 210Po, the latter was assumed as the ending isotope of a simplified 4n+2 decay chain There are identified the main contributors to the variance of model output. The reduction of uncertainties of those parameters would lead to the decrease of spread of model output.

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