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Development of an Insight Model for Post-closure Radiological Risks from the Disposal of High-level Waste and Spent Fuel

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Geological disposal is the UK policy for the long-term management of higher activity radioactive wastes. The Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority (NDA) has been given the responsibility for implementing geological disposal in the UK.
The approach adopted for building confidence in long-term safety of the GDF is to use multiple barriers to isolate and contain the wastes. NDA-RWMD proposes to develop a safety case based on varied and different lines of reasoning, including both quantitative aspects and qualitative safety arguments. This paper describes the development of a simplified model for high-level waste (HLW) and spent fuel (SF).
Assessments of HLW and SF disposals need to reflect a number of physical and chemical processes that govern the release and transport of the disposed wastes. Physical processes include container failure, release of radionuclides from the wasteform, diffusion through bentonite barriers and transport in fractured rock. Chemical processes include solubility limitation and sorption. HLW and SF assessments are generally based on numerical models of these processes, implemented in software tools such as GoldSim. The results of such assessments can be complex to understand, especially in situations where no single release or transport process is dominant.
A simplified model of the release and transport of radionuclides for disposals of HLW and SF has been developed. The objectives of the model are to identify the key physical and chemical processes that govern radiological risk, and to enable numerical estimates of risk (and other intermediate quantities) to be made. The model is based on the notion that the properties of the time-dependent model outputs can be characterised in terms of “moments”. The moments are easy to compute since they are related in a simple way to the Laplace transforms of the functions under consideration. The Laplace transform method is a standard technique for solving the governing equations for release and transport of radionuclides. A number of mathematical theorems enable the moments of outputs for coupled systems to be expressed in terms of the moments of individual subcomponents.
Use of this model demonstrates that approximations to peak risk and other intermediate quantities can be derived that bring out clearly the relative importance of the underlying physical and chemical processes. In this way the key processes can be identified for each radionuclide, and hence the key governing parameters can be identified. This is achieved without the need to develop or execute detailed numerical models of radionuclide release and transport.
The model has been implemented in a spreadsheet, and has been tested against the results of detailed assessments undertaken by NDA-RWMD for scenarios involving disposal of HLW and SF using the Swedish (KBS-3) concept. Although such a simplified model will not replace detailed numerical models as the main tools for assessing risk, the model provides ready insight to the key controlling features of the system which can be difficult to achieve using only detailed numerical models.