

Simulation of Radionuclide Transport in Fractured Porous Media

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Date: 2024/11/08

Abstract

High-level radioactive waste (HLW) contains materials with high radioactivity and toxicity. Deep geological disposal with multi-barrier system is a widely accepted international approach for final disposal of HLW. Performance and safety assessments and transport simulations are essential to ensure effective containment and isolation of these radionuclides, minimizing radiation exposure risks to humans and the environment. When the host rock is hard (e.g., granite), water flow primarily occurs through fractures, and radionuclides may also diffuse into the rock matrix. Therefore, simulations of radionuclide transport in fractured porous media are crucial for safety assessments.

To model solute transport in fractured porous media, this study employs the developing NCU_TW-Hybrid_FEM model, which has been benchmarked against international case studies and can simulate solute transport in fractured porous media. This study also intends to validate the model using a natural case, to support radionuclide transport modeling in fractured porous media. Literature reviews and preliminary testing are underway. The model aims to enhance accuracy and reduce uncertainty in radionuclide transport simulations in fractured porous media, thereby increasing confidence in safety assessments for deep geological disposal and ensuring the long-term safety and effectiveness of HLW final disposal.

Keywords: HLW final disposal, Radionuclide transport, Fractured porous media, NCU_TW-Hybrid_FEM.

裂隙-孔隙介質內的放射性核種傳輸模擬

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報告日期：2024/11/08

摘要

高放射性廢棄物包含許多具有高放射性與毒性之物質。為確保高放射性廢棄物最終處置的安全性，國際間普遍採用深層地質處置與多重障壁系統的設計概念，並結合安全與性能評估及核種傳輸模擬，以確保深層地質處置設施能有效隔離和圍阻放射性物質，最大限度地減少人類和環境的輻射暴露風險。若多重障壁系統不幸遭受破壞，放射性物質將隨地下水流移動，當處置母岩為堅硬岩體(如：花崗岩)時，水流主要透過裂隙傳輸，放射性物質亦可能擴散至母岩基質內，因此模擬評估需考量裂隙-孔隙介質中放射性核種化學反應與傳輸行為。

為模擬裂隙-孔隙介質中的溶質傳輸行為，本研究將採用目前正在開發中的 NCU_TW-Hybrid_FEM 模式。該模式已經過國際案例比對，可用於模擬裂隙-孔隙介質中的溶質傳輸行為。本研究亦欲使用現地分析數據對該模式進行驗證，証實模式之可信度，以利未來執行裂隙-孔隙介質內的放射性核種傳輸模擬。目前進行文獻資料蒐集與初步測試，希望所開發的模式可以提高裂隙-孔隙介質中放射性核種傳輸模擬的準確性，並減少不確定性，以增強深層地質處置安全評估的信心，確保高放射性廢棄物最終處置的長期安全性和有效性。

關鍵字：高放射性廢棄物最終處置、放射性核種傳輸、裂隙-孔隙介質、NCU_TW-Hybrid_FEM。