Contribution ID: **232** Type: **Oral Presentation**

A Darcy scale coupled fluid-thermal framework to model radionuclide transport from a deep disposal borehole

Monday, 31 May 2021 15:55 (15 minutes)

Waste packages for disposal of radioactive waste originating from reprocessing of spent nuclear fuel typically include a stainless steel canister inside which the waste is immobilised in a (borosilicate) glass matrix. A potential disposal pathway for such wastes is in conventional mined geological disposal facilities (GDF) [1] or in deep boreholes [2]. In the latter concept, the packages are stacked in a disposal zone at a depth of several kilometres [3]. However, deep borehole disposal is still in its infancy requiring considerable Research, Development and Demonstration (RD&D) to bring the science to a similar level as for GDFs [4].
It is estimated that the total global inventory of radioactivity confined within (borosilicate) glass from reprocessing is on the order of 10^{20} Bq, with an approximate weight of 15,000 metric tonnes [5, 6]. The half-life of some of the radionuclides in nuclear waste is from the order of $10^5 - 10^9$ y (e.g. ^{135}Cs, ^{79}Se, ^{238}U, etc) [6]. This waste will generate heat for several hundred years [7, 8]. Any disposal container should have a lifetime long enough to survive (i.e. no breach therefore zero release) the heat-production period.
For clay sediments, a porous medium-type pore network is the path through which transport occurs [9]. For crystalline rocks on the other hand, transport is typically through a fracture network with concomitant matrix diffusion [1]. The nonlinear interaction between different transport phenomena and the very long time scales of the processes involved, necessitates modelling as the most realistic tool to assess the risks to humans and the environment [10]. Given the much greater disposal depth of a deep borehole concept compared to conventional GDFs, and the heat-generating feature of the disposed waste, temperature evolution and its potential impact on radionuclide migration has to be accounted for in post-closure safety assessments.
For conventional GDFs, several studies have been conducted to model the thermal, hydraulic and mechanical interactions within the near field of the disposal environment [11]. The majority of these post-closure safety assessments consider isothermal transport of dissolved radionuclides, using simulation codes such as FRAC and PORFLOW [10, 12]. Some studies have also used TOUGH an TOUGHREACT to couple other transport phenomena [13]. However, few modelling studies exist for deep borehole disposal which include a proper linkage between the natural hydrostatic and temperature profiles to heat and solute mass transport at the Darcy scale [14, 15].
Here we present a coupled heat and solute mass transport modelling framework, subjected to depth-dependent temperature, pressure and viscosity profiles - assuming an instantaneous release of all radionuclides. This is a very conservative assumption but is consistent with typical "what if?"scenarios undertaken in post-closure safety assessments [16]. The TOUGHREACT code [17, 18] was used in an axi-symmetrical domain with a total depth of 3200 m. Several scenarios of heat-generation were investigated to test if the additional heat produced by the waste containers affects radionuclide migration, e.g. by generating convection-driven mass transport. Results show that the heat generation does not significantly affect the extent of the solute mass plume.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

1. De Windt, L. and N.F. Spycher, Reactive Transport Modeling: A Key Performance Assessment Tool for the Geologic Disposal of Nuclear Waste. Elements, 2019. 15(2): p. 99-102.
2. Freeze, G.A., et al., Deep Borehole Disposal Safety Case. 2019, Sandia National Lab.
3. Arnold, B.W., et al., Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste. 2011, Sandia National Laboratories.
4. Mallants, D., et al., - The State of the Science and Technology in Deep Borehole Disposal of Nuclear Waste. 2020. - 13(- 4).
5. Verney-Carron, A., S. Gin, and G. Libourel, Archaeological analogs and the future of nuclear waste glass. Journal of Nuclear Materials, 2010. 406(3): p. 365-370.
6. Poinssot, C. and S. Gin, Long-term Behavior Science: The cornerstone approach for reliably assessing the long-term performance of nuclear waste. Journal of Nuclear Materials, 2012. 420(1): p. 182-192.
7. Johnson, L., Demonstration of feasibility of disposal ("Entsorgungsnachweis") for spent fuel, vitrified high-level waste and long-lived intermediate-level waste. 2002, Nagra: Wettingen (Switzerland).
8. Mallants, D. and Y. Beiraghdar. Heat Transport in the Near Field of a Deep Vertical Disposal Borehole: Preliminary Performance Assessment. in WM2018 Conference. 2021. Phoenix, Arizona.
9. Ewing, R.C., R.A. Whittleston, and B.W.D. Yardley, Geological Disposal of Nuclear Waste: a Primer. Elements, 2016. 12(4): p. 233-237.
10. Mallants, D., J. Marivoet, and X. Sillen, Performance assessment of the disposal of vitrified high-level waste in a clay layer. Journal of Nuclear Materials, 2001. 298(1): p. 125-135.
11. Son, N.T., et al., Modelling a heater experiment for radioactive waste disposal. Environmental Geotechnics, 2019. 6(2): p. 87-100.
12. Huysmans, M. and A. Dassargues, Hydrogeological Modeling of Radionuclide Transport in Heterogeneous Low-Permeability Media: A Comparison Between Boom Clay and Ieper Clay, in geoENV VI –Geostatistics for Environmental Applications: Proceedings of the Sixth European Conference on Geostatistics for Environmental Applications, A. Soares, M.J. Pereira, and R. Dimitrakopoulos, Editors. 2008, Springer Netherlands: Dordrecht. p. 211-219.
13. Scheer, D., H. Class, and B. Flemisch, Nuclear Energy and Waste Disposal, in Subsurface Environmental Modelling Between Science and Policy, D. Scheer, H. Class, and B. Flemisch, Editors. 2021, Springer International Publishing: Cham. p. 179-192.
14. Jacquey, A.B., M. Cacace, and G. Blöcher, Modelling coupled fluid flow and heat transfer in fractured reservoirs: description of a 3D benchmark numerical case. Energy Procedia, 2017. 125: p. 612-621.
15. Ackerer, P., A. Younès, and M. Mancip, A new coupling algorithm for density-driven flow in porous media. Geophysical Research Letters, 2004. 31(12).
16. Mallants, D. and N. Chapman, How much does corrosion of nuclear waste matrices matter. Nature Materials, 2020. 19(9): p. 959-961.
17. Jung, Y., et al., TOUGH3: A new efficient version of the TOUGH suite of multiphase flow and transport simulators. Computers & Geosciences, 2017. 108: p. 2-7.
18. Xu, T., et al., TOUGHREACT User's Guide: A Simulation Program for Non-isothermal Multiphase Reactive Geochemical Transport in Variably Saturated Geologic Media, V1.2.1. 2008, Lawrence Berkeley National Lab. (LBNL).

Acceptance of Terms and Conditions

Click here to agree

Newsletter

I do not want to receive the InterPore newsletter

Student Poster Award

Primary authors: Dr SOOKHAK LARI, Kaveh (CSIRO); Dr MALLANTS, Dirk (CSIRO)

Presenter: Dr SOOKHAK LARI, Kaveh (CSIRO)

Session Classification: MS17

Track Classification: (MS17) Thermal Processes, Thermal Coupling and Thermal Properties of Porous Media: modeling and experiments at different scales