Fracture flow and radionuclide transport in granitic rock

Pirkko Hölttä[1] and Antti Poteri[2]

[1]*University of Helsinki, Laboratory of Radiochemistry*

[2]*VTT Nuclear Energy*

Introduction

Block fracture and core column migration experiments were performed to evaluate the simplified radionuclide transport concept used in assessing the safety of the underground waste repositories. The objectives were to examine matrix diffusion and to estimate retention processes in different scales and flow conditions.

Experimental

Kuru grey granite block

Natural fracture 0.9 x 0.9 m, main flow channel 0.75 m, channel width 0.06 m, aperture 0.65 mm.

Core columns

0.75 m, 0.68 m, 0.28 m drill cores placed inside tubes, flow channel in the gap between the cores and tube walls.

Tracer tests: Uranine, HTO, ^{131}I, ^{22}Na, flow rates of 0.7–50 µl·min^{-1}.

Fig. 1. Set-ups for radionuclide migration experiments; Kuru grey granite block (left) and core columns (right).

Modelling approach

Advection-dispersion model based on the generalized Taylor dispersion assuming a linear velocity profile across the flow channel (1).

Solute discharge at the end of the transport channel (2)

Matrix diffusion property (u) (3).

$$C_m = \frac{1}{2}\left(erf\left[\frac{\frac{1}{2}X_s + X + \xi_1}{2\sqrt{\xi_2}}\right] + erf\left[\frac{\frac{1}{2}X_s - X - \xi_1}{2\sqrt{\xi_2}}\right]\right);$$

$$\xi_1 = -\frac{1}{2}\tau;\ \xi_2 = \left(\frac{1}{(Pe)^2} + \frac{1}{120}\right)\tau - 8\sum_{n=0}^{\infty}\frac{1-e^{-(2n+1)^2\pi^2\tau}}{(2n+1)^8\pi^8};\quad (1)$$

$$\tau = \frac{Dt}{a^2};\ X = \frac{Dx}{a^2 v_0};\ X_s = \frac{Dx_s}{a^2 v_0};\ Pe = \frac{a v_0}{D}$$

$$j(t, t_w, u, R_a) = H(t - R_a t_w)\frac{u}{\sqrt{\pi}(t - R_a t_w)^{3/2}} e^{-\frac{u^2}{t - R_a t_w}} \quad (2)$$

$$u = \varepsilon\sqrt{D_p R_p}\frac{W L}{Q} = \varepsilon\sqrt{D_p R_p}\frac{t_w}{2b} \quad (3)$$

D = molecular diffusion coefficient in water
a = width of the velocity profile
x_s = initial width of the tracer plume
v_0 = maximum flow velocity
t = time
x = position along the channel
t_w = ground water transit time
$2b$ = channel aperture
D_p = matrix pore diffusivity
ε = porosity
R_a = surface retardation coefficient
R_p = retardation coefficient in the matrix

Results

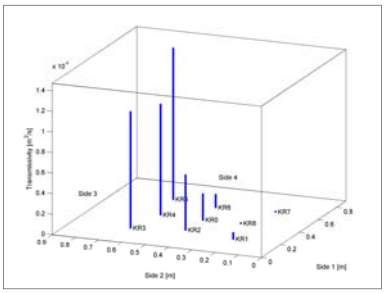

Fig. 2. Local transmissivities determined from the water consumption tests in the drill holes.

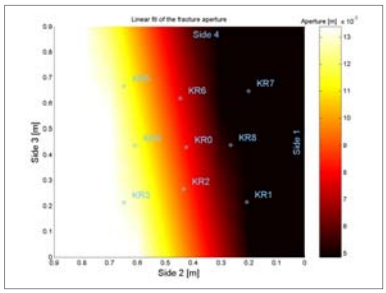

Fig. 3. Linear fit of the fracture aperture calculated from the transmissivities.

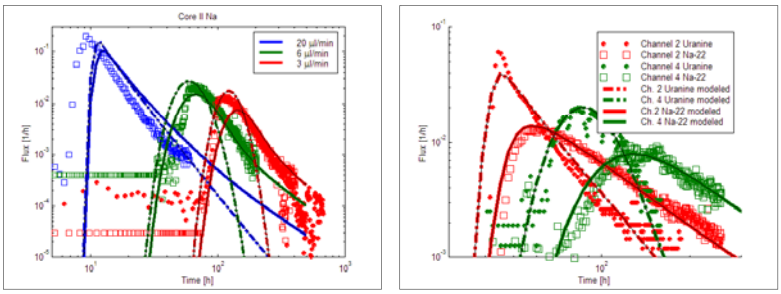

Fig. 4. Modelled and measured breakthrough curves of ^{22}Na through the natural fracture (right) and the 0.68 m column (left). Solid lines are modelled results for advection-dispersion and matrix diffusion. Dotted lines are for the advection-dispersion only.

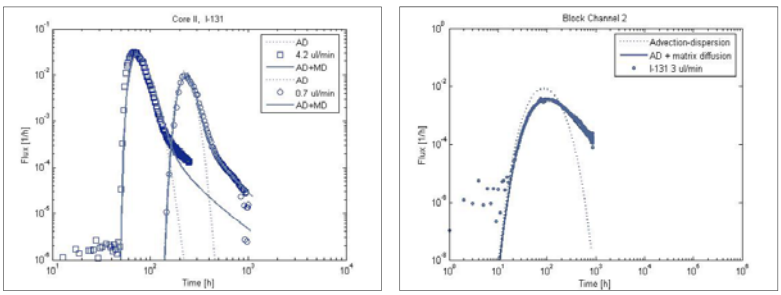

Fig. 5. Modelled (solid line) and measured breakthrough curves of ^{131}I through the natural fracture (right) and through the 0.68 m column (left).

Conclusions

Two different experimental configurations could be modelled applying a consistent parameters and transport processes.

The effects of matrix diffusion were demonstrated on ^{22}Na and ^{131}I breakthrough curves.

This understanding is transferable from laboratory scale to in–situ conditions though results can not be transferred directly to the spatial and temporal repository scale.

References

Hölttä, P., Poteri, A., Hakanen, M. and Hautojärvi, A., 2004. Radiochimica Acta 92, 775–779.

Hölttä, P., Poteri, A., Siitari-Kauppi, M. and Huittinen, N., 2008. Physics and Chemistry of the Earth 33, 14–16, 983–990.