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**TIME-DEPENDENT NUCLIDE TRANSPORT THROUGH BACKFILL INTO A FRACTURE**

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# Time-Dependent Nuclide Transport Through Backfill into a Fracture*

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Fractures (fissures) in the emplacement rock of a geologic repository of nuclear waste may intersect boreholes for waste packages, providing conductive pathways for hydrogeologic transport of radionuclides. Previous study[1] of transport through backfill into a fissure considered only steady-state transport of a stable species. The U. S. regulatory framework[2] for geologic disposal is for much shorter time scales and requires calculation of time-dependent radionuclide transport into fractures. In this paper we present a transient analysis of radionuclide transport through backfill into a fissure.

As shown in Figure 1, we consider a waste canister surrounded by backfill in a borehole intersected by a fracture, in water-saturated rock. Radionuclides are released at a constant concentration $C_s$ at the waste surface into the backfill. Ground water flows in the fissure. We assume no ground-water flow in the backfill, so that radionuclide transport through the backfill is controlled by molecular diffusion. The rock matrix is assumed to be completely impervious, thus mass transport in the rock takes place in the fracture only. The mass flux into the rock is given by the mass transfer coefficient $h$ times the average nuclide concentration $\bar{C}$ across the fissure mouth. For a small hole-to-canister radius ratio, cylindrical geometry can be simplified to planar geometry by unfolding the cylinder into a rectangular parallelepiped. This problem has been solved analytically,[3] and we present a numerical illustration using planar geometry.

Figure 2 shows the dimensionless mass transfer rate $\dot{M}/2\pi r_2 b C_s h$ versus the Fourier modulus $Dt/d^2$, with the square of the modified Thiele modulus $\lambda d^2/D$ as a parameter. Here $D \equiv D_f/K$, where $D_f$ is the species diffusion coefficient, $K$ the species retardation coefficient in backfill, $\lambda$ the decay constant, $d$ the backfill thickness, and $t$ the time variable. The graph applies for an assumed value of the Sherwood number $(hd/\epsilon D_f)$ of unity, in which $\epsilon$ is the porosity, and the graph represents a condition of mass-transfer-limited dissolution. At early time mass transfer into the backfill is large due to the steep concentration gradient near the waste surface. As time increases nuclide concentration builds up in the backfill, and the mass

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transfer rate decreases and approaches steady state. Nuclide transfer into the fissure is zero at early times and increases as nuclides diffuse through the backfill, until steady state is reached. For a stable nuclide ($\lambda d^2/D \equiv 0$) the mass transfer rates into backfill and into the fissure become equal at steady state. For decaying radionuclides ($\lambda d^2/D \neq 0$) the general trend of mass transfer is the same as for a stable nuclide. Radioactive decay steepens concentration gradients near the waste surface and increases mass transfer into the backfill. The time to reach steady state is shorter for decaying radionuclides than for a stable nuclide.

This numerical illustration of a transient analysis of radionuclide transport through backfill into a fracture shows that time-dependent effects are significant. This contribution will aid the performance assessment of waste packages in nuclear waste repositories.

## References

1. I. Neretnieks, 1986, "Stationary Transport of Dissolved Species in the Backfill Surrounding a Waste Canister in Fissured Rock: Some Simple Analytical Solutions," *Nucl. Technol., 72,* 194

2. 41 *Code of Federal Regulations*, Part 191

3. P. L. Chambré, to be published

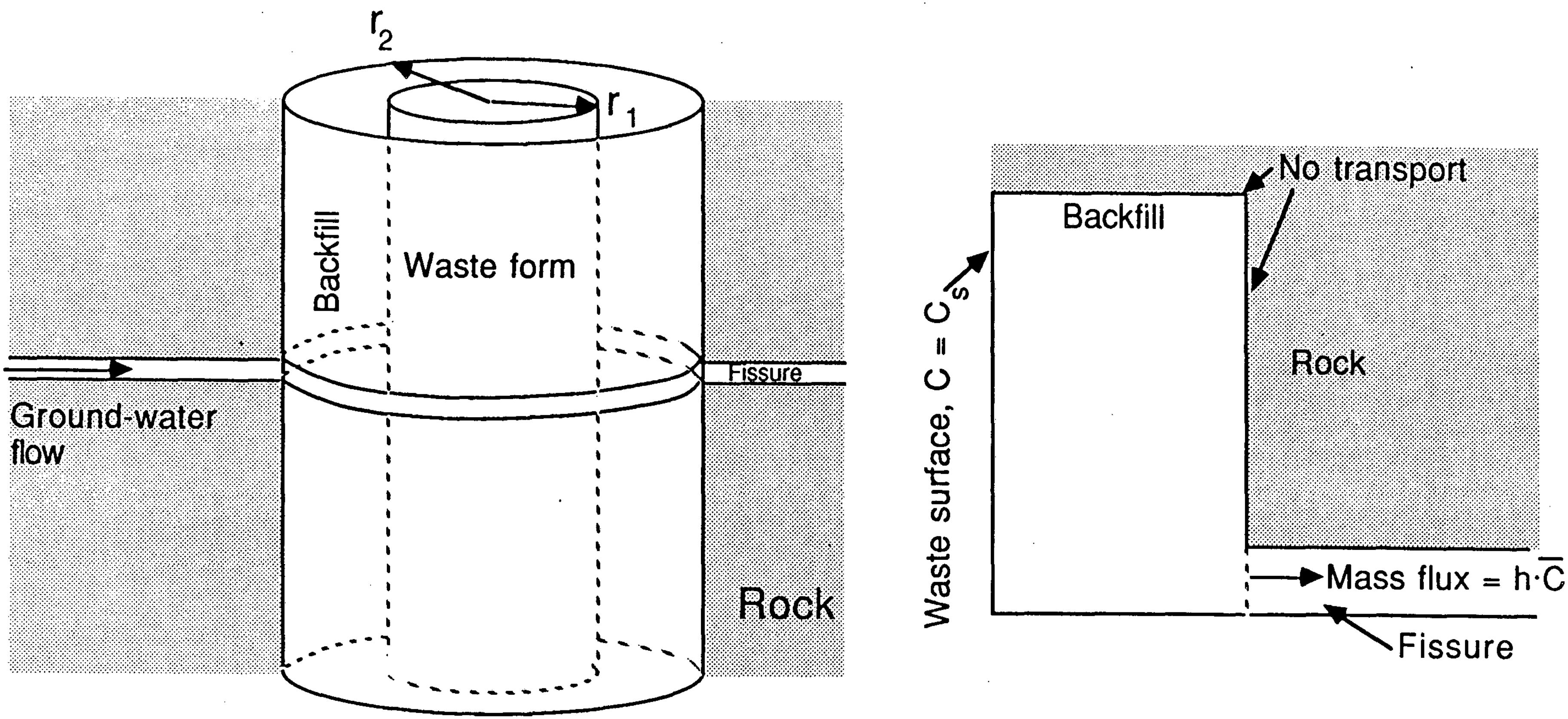


Figure 1 Waste package intersected by a fissure

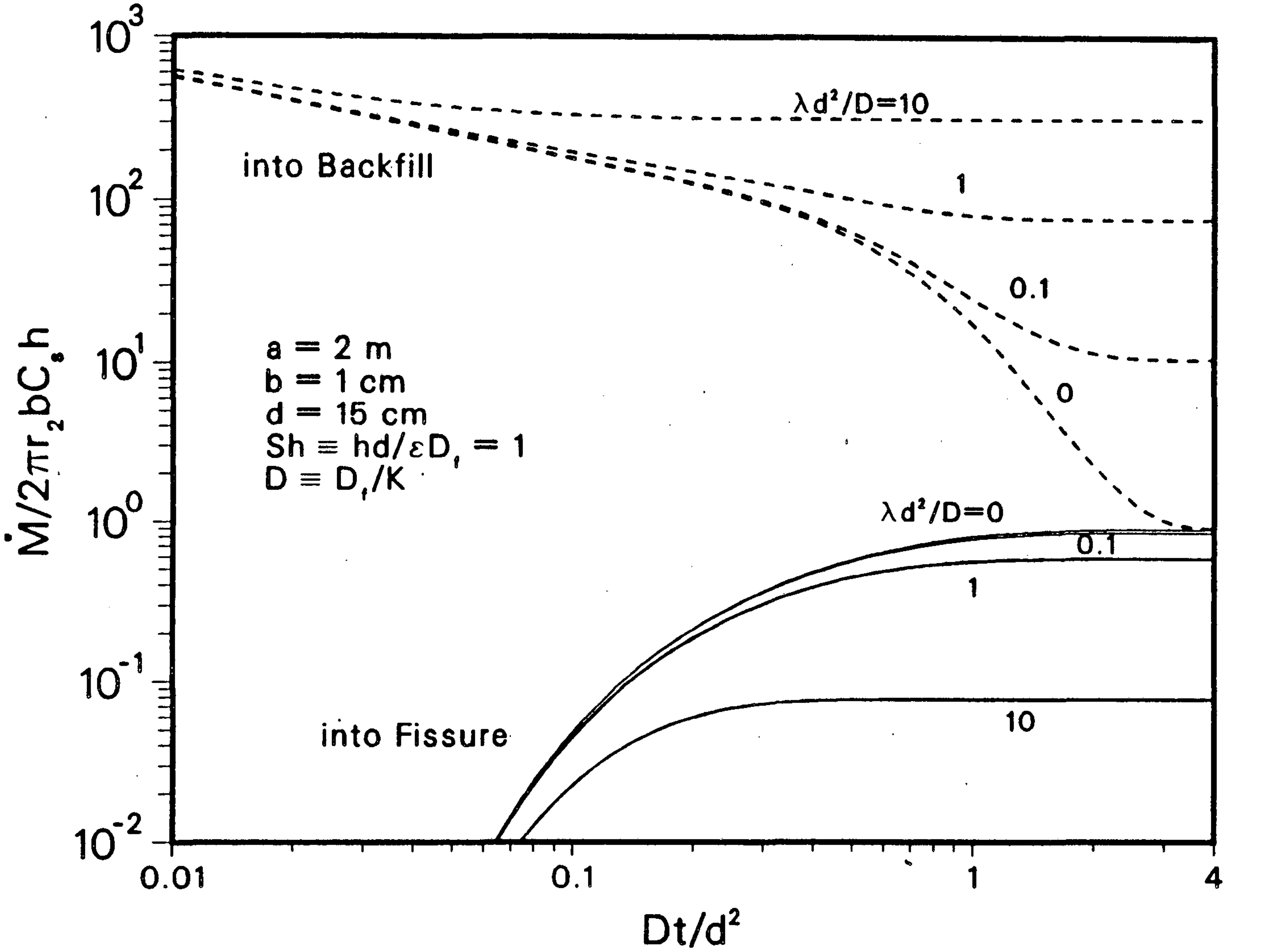


Figure 2. Mass Transfer Rate into the Backfill and into the Fissure versus Fourier Modulus with the Modified Thiele Modulus as a Parameter.