Discovery at the Interface of Science and Engineering: Science Matters!

Engineering Sciences
Fluid Science

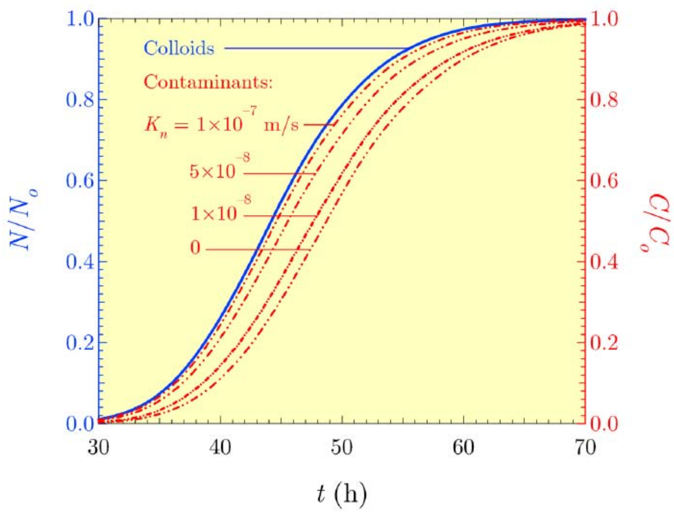

Figure 1: Normalized colloid (blue) and contaminant (red) breakthrough curves where increasing reaction rate of the contaminants with the colloids collapses the contaminant curve onto the colloid curve. Here, no natural attenuation processes are considered.

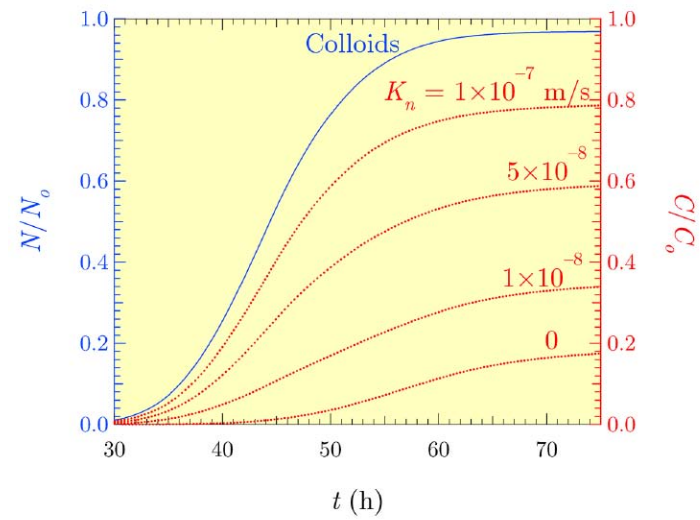

Figure 2: Normalized colloid and contaminant curves when natural attenuation processes retard breakthrough. Note that still, about 97% of the colloids exit the system, but much fewer contaminants do unless they are associated with the colloids (higher co-transport reaction rates).

Colloids and Buried Radioactive Waste

Sorption of contaminants onto colloids can dramatically affect their mobility in porous media.

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Hazardous wastes, especially radioactive materials, are often disposed in canisters and buried in deep, fractured, low-permeability rock formations (e.g., granite, mudstone, shale, volcanic rock, and clay). The science behind safe, deep geologic sequestration and disposal is an enormous concern. For example, the Department of Energy (DOE) has invested considerable effort at the Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain Repository.

In the event of container rupture, dispersal of hazardous waste in groundwater may be aided by colloids, which are very fine particles that range in diameter from the nanometer to the micron scales, and are chemically similar to subsurface material (clay minerals, metal oxides, silicic acid, and organic matter). Colloids are the groundwater equivalent of dust particles in air. Because a colloid has a high surface area per unit mass, it possesses a high sorptive capacity for dissolved contaminants. Thus, contaminants could migrate not only as dissolved species in the liquid phase, but also when adsorbed onto suspended colloidal particles.

A critical issue, therefore, is whether colloids actually enhance contaminant migration from buried hazardous wastes. To examine this possibility, Sandia researchers are developing colloid-facilitated contaminant transport models. In a model shown here (Figures 1 and 2), colloids and contaminants are introduced at the inlet of a single, variable-aperture fracture. Results represent the ensemble average of 100 stochastic realizations of the geologic fracture and indicate the mass fraction (breakthrough) exiting the fracture outlet. In Figure 1, colloid (blue) and contaminant (red) breakthrough curves are given in the case when there is no natural attenuation for the migration of the dissolved component, such as diffusion into the surrounding matrix or chemical reactions with the fracture surface. In this case, the red curves collapse onto the faster moving colloid curve with increasing reaction tendency (K_n) to bind to the colloids.

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The colloids are faster moving because they are excluded from most small pore spaces and tend to stay in the fastest moving portions of the flow field because of shear gradients and resulting pressure differences across their diameters. When natural contaminant attenuation mechanisms are taken into account, the results are dramatically different (Figure 2). In this more realistic case, the colloids essentially shield the contaminants from retardation because they typically do not react with fracture surfaces and cannot penetrate the small pore spaces of the surrounding rock. The models thus show that colloids can serve as efficient carriers for contaminants, and significantly enhance their net migration rate, especially in fractured rock formations.

The models are consistent with observations in the field. For example, at the Nevada Test Site, radionuclide analyses for detonation-cavity samples indicated that substantial fractions of selected nuclides are found on natural colloids. In another example, at two separate sites in Los Alamos, plutonium and americium were detected at orders of magnitude greater distances from the source than predicted by dissolved-contaminant transport models. Clearly, taking into account the potential for colloids to facilitate contaminant transport is a key concern for both national and international repository programs.

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