Category III - Water Quality

Emplacement and Release of Brines from the Subsurface

James R. Hunt
Civil and Environmental Engineering
University of California
Berkeley, CA 94720-1710
Phone: 510-642-0948
Fax: 510-642-7483
Email: hunt@ce.berkeley.edu

Executive Summary:

Groundwater contamination resulting from the creation and release of dense brines is a common occurrence, but is rarely acknowledged. Brines can be generally defined as aqueous solutions with a total dissolved solids (TDS) concentration in excess of 10,000 mg L^{-1}. In addition to increased TDS, brines have a greater density and viscosity than that of freshwater. The most widespread and widely recognized occurrence of brine-induced groundwater contamination is seawater intrusion into coastal aquifers. Seawater has a TDS concentration of about 30,000 mg L^{-1} and a density and viscosity only slightly greater than that of freshwater, making it relatively innocuous as a brine. Other examples of groundwater contamination resulting from brine releases are ammonium perchlorate spills, acid mine drainage, landfill leachate plumes, and unintentional releases from nuclear waste processing facilities. TDS concentrations of these highly concentrated brines can be in excess of 500,000 mg L^{-1} with densities and viscosities much greater than that of freshwater. Since most spills occur at or near the land surface, brines can contaminate aquifers only if they reach the groundwater table through infiltration through the vadose zone. The vadose zone has the potential of being a long-term source of brine contamination of drinking water aquifers.

Little is currently understood about the transport of brines in the vadose zone. The ultimate objective of this research is to increase the understanding of brine fate by quantifying vadose zone transport mechanisms, but this also requires some effort to understand brine migration in water saturated porous media. During brine release at the soil surface, the brine moves as a wetting fluid vertically through the vadose zone, displacing residual pore water at the wetting front. At the brine/freshwater interface, gravitational instabilities will induce mixing. Once the brine release has stopped, the vadose zone will drain to residual brine saturation. During subsequent freshwater infiltration events, the freshwater wetting front displaces residual brine and creates a brine “halo” ahead of the freshwater wetting front. At this freshwater/brine interface viscous instabilities will induce mixing since the viscosity of the displacing freshwater is less than the viscosity of the brine.

A laboratory-scale experimental program has been established to specifically address the issues of mixing at the unstable brine/freshwater interfaces. This experimental program takes place in two phases. During the first phase, fully saturated, one-dimensional vertically downward displacements, the mixing zone is measured as brine displaces freshwater and as freshwater displaces brine. The dependence of mixing zone size as a function of brine physical parameters, i.e. density and viscosity, and experimental parameters, i.e. displacement rate, column permeability, and column diameter, will be determined. Experimental data reported by others indicate that as brine displaces freshwater, the flow will be gravitationally unstable, but will be stabilized by the viscosity difference. The gravitational instability tends to dominate over the viscous stabilization and overall mixing is enhanced. As freshwater displaces brine, the flow will be gravitationally stable, but will be destabilized by the viscosity difference. The gravitational stabilization tends to dominate over the viscous destabilization and overall mixing is suppressed. Expected completion of the first experimental phase is September 1, 2002. The second experimental phase, unsaturated one-dimensional vertically downward displacements, will repeat the experiments of phase 1 in an unsaturated system. Expected completion of the second experimental phase is April 1, 2003.