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On the interaction between gravity forces and dispersive brine fronts in micro-heterogeneous porous media

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Abstract

The concepts of homogenization theory are employed to derive a macro-scale brine transport equation for micro-heterogeneous porous medium of layered structure under assumptions of validity of classical Darcy's law and Fick's law at the local scale. Derived macro-scale model is analogous to the so-called phase field equations. The obtained results are verified with direct numerical experiment.

Keywords: Brine transport; Density dependent flow; Homogenization theory; Hydrodynamic dispersion

1. Introduction

The safe disposal of hazardous chemical and radioactive waste is most likely one of the key environmental issues in industrialized and densely populated countries. Many alternative methods were suggested and intensively assessed w.r.t. feasibility and long-term environmental safety. Amongst others, we mention the storage of high-level radioactive waste in subsurface salt-rock formations. In the groundwater system in the vicinity of such salt-rock formations, high salt concentrations can be observed, up to the saturation limit of salt in water, corresponding to a (bulk) fluid density of approximately 1300 kg/m^3. In case of a calamity with such a repository, transport of hazardous contaminants through the groundwater system was identified to be the most probable transport mechanism towards the biosphere. Obviously, most of the research focused on contaminant transport, and in particular on the role of the naturally occurring high salt concentrations and high-concentration-gradients.

Independently conducted stable brine displacement experiments by Hassanizadeh et al. [1], Moser [2], and Watson [3] showed that brine transport in porous media cannot be modeled using classical (linear) Fick's Law for the dispersive salt mass flux. A significant decrease of the apparent dispersivity was observed when the density difference between the resident fluid (fresh water) and the displacing fluid (brine) was increased. This phenomenon is believed to be due to the stabilizing action of gravity. Hydrodynamic dispersion is the macroscopic outcome of enhanced mixing due to local velocity differences which are caused by local permeability variations (heterogeneities) in the porous medium. In case of low density differences between the displacing fluids, i.e. "tracer" concentrations, linear Fick's Law is commonly used to model the macroscopic dispersive mass flux. However, when high-concentration-gradients are present, gravity forces, acting at the small-scale, stabilize the front between brine and water. Local

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