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Computational study on miscible viscous fingering dynamics with non-linear adsorption

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The transport of the solute in porous media is affected by its interaction with the surface of the system. For instance, adsorption of the solute on the porous matrix can alter its distribution dynamics. The adsorption in most of the physical processes like water pollution, soil contamination or in chemical processes like chromatography, is correctly predicted by non-linear Langmuir adsorption isotherm [1]. The Langmuir adsorption of the solute concentration results in self-sharpening of the profile. On the other hand, the dispersion of the solute concentration leads to smoothening of the profile. The two simultaneous processes, self-sharpening and smoothening, lead to the formation of a shock layer [2].
For an unfavorable viscosity contrast between the underlying miscible fluids a hydrodynamic instability, called viscous fingering (VF) [3], can alter the solute transport. The mass distribution in a porous media thus gets affected by the VF as well as by the Langmuir adsorption of the solute on the surface. Our main focus is to develop a numerical technique to capture the shock layer profile of the solute and to investigate the alterations in its distribution dynamics under the effect of VF instability.
A two dimensional model of the solute adsorption on the porous matrix is modeled by coupling the momentum balance equation in the form of Darcy's law with the mass balance equation for the adsorbed solute. Since, the non-linear adsorption of the solute leads to hyperbolicity in the mass conservation equation, thus we developed a spectral method to numerically solve the governing system of equations [4]. In the numerical technique the non-linear terms in the mass balance equation are computed pseudo-spectrally, hence it successfully captures the shock layer profile. Further, with the introduction of viscosity contrast between the interplaying fluids, an earlier onset of viscous fingering can be obtained and different complex dynamical patterns on solute distribution have been observed.

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