



Toward an improved description of the physics of two-phase flow

S. Majid Hassanizadeh

National Institute of Public Health and Environmental Protection (RIVM), PO Box 1, 3720 BA Bilthoven, The Netherlands

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William G. Gray

Department of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, Indiana 46556-0767, USA

The present work incorporates the effects of interface dynamics into the theoretical description of two-phase flow in a porous medium. This advance offers the potential for improved understanding and modeling of multiphase flow processes. To provide background for this work, the traditional approach to describing two-phase flow in porous media is reviewed. The universally employed empirical extension of Darcy's Law for single-phase flow to two-phase flow situations is rejected as arbitrary and subject to severe shortcomings. Burial of dynamic effects into relative permeability and capillary pressure hysteresis is shown to be an unsatisfactory theoretical construct for modeling the actual processes occurring in two-phase flow. Examination of the traditional theory at equilibrium shows that interfacial forces actually present in multiphase systems have been overlooked causing the theory to provide contradictory results. To overcome these problems, a general theory of two-phase flow is proposed that is based on the basic principles of mass, momentum, and energy conservation and the second law of thermodynamics. This theory accounts, in a systematic way, for interfacial forces that are known to have an important effect on the movement of fluid phases in a porous medium. A new equation of momentum balance accounting for the presence of interfaces and their energetics is developed. This equation reduces to Darcy's Law for the special case of single-phase flow. The extended theory has the potential to describe phenomena unaccounted for by the traditional theory and thus provides a basis for scientific understanding of the physics of two-phase flow. Application of the theory requires experimental study to ascertain the values and precise functional dependence of the constitutive coefficients that arise.

Key words: Unsaturated flow, two-phase flow, Darcy's law, interfacial areas, capillary pressure