Transport in Porous Media **23:** 107–124, 1996.

On the Transient Non-Fickian Dispersion Theory

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(Received: 20 June 1995; in final form: 11 December 1995)

Abstract. The Fickian dispersion equation is the basic relationship used to describe the nonconvective mass flux of a solute in a porous medium. This equation prescribes a linear relationship between the dispersive mass flux and the concentration gradient. An important characteristic of the Fickian relationship is that it is independent of the history of dispersion (e.g. the time rate of change of the dispersion flux). Also, the dispersivities are supposed to be medium constants and invariant with temporal and spatial scales of observation. It is believed that in general these restrictions do not hold. A number of authors have proposed various alternative relationships. For example, differential equations have been employed that prescribe a relationship between the dispersion flux and its time and space derivatives. Also, stochastic theories result in integro-differential equations in which dispersion tensor grow asymptotically with time or distance. In this work, three different approaches, which lead to three different non-Fickian equations with a transient character, are discussed and their primary features and differences are highlighted. It is shown that an effective dispersion tensor defined in the framework of the transient non-Fickian theory, grows asymptotically with time and distance; a result which also follows from stochastic theories. Next, principles of continuum mechanics are employed to provide a solid theoretical basis for the non-Fickian transient dispersion theory. The equation of motion of a solute in a porous medium is used to provide a rigorous derivation of various dispersion relationships valid under different conditions. Under various simplifying assumptions, the generalized theory is found to agree with the conventional Fickian theory as well as several other non-Fickian relationships found in the literature. Moreover, it is shown that for nonconservative solutes, the traditional dispersion tensor is affected by the rate of mass exchange of the solute.

Key words: solute transport, Fick's law, dispersion, dispersivity, equation of motion, non-Fickian dispersion equation, scale effects.