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Theory for dynamic dispersion in Poiseuille and Hagen-Poiseuille flow

Wang, L.[1], Cardenas, M. B.[1], Deng, W.[1]
wanglichun@utexas.edu
1. Jackson School of Geosciences, The University of Texas at Austin, Austin, TX

We present a theory for the dynamic dispersion coefficient (D) for transport by Poiseuille (parallel plate) and Hagen-Poiseuille (tube) flow, the foundation for models of many natural systems, such as in fractures or rivers and conceptualized capillary tubes in the context of porous media. The theoretical model is validated by comparing the breakthrough curves (BTCs) from a 1D advection-dispersion model with dynamic D to that from direct numerical solutions utilizing a 2D advection-diffusion model.

Both Taylor dispersion theory and our new theory are good predictors of D at lower Peclet Number (Pe) regime, but gradually fail to capture most parts of BTCs as Pe increases. However, our model generally predicts the mixing and spreading of solutes better than Taylor's theory since it covers all transport regimes from molecular diffusion, through anomalous transport, and to Taylor dispersion. The model accurately predicts D based on the early part of BTCs even at relatively higher Pe regime where the Taylor's theory fails. Furthermore, the model allows for calculation of the time and length scale that separates Fickian from non-Fickian transport. Therefore, transport has to occur over a relatively long domain or long time for the classical advection-dispersion equation to be valid.

Keywords: Dynamic dispersion, Taylor dispersion, Poiseuille flow, Hagen-Poiseuille flow