ABSTRACT

Diffusion and dispersion are the two basic processes that control the overall transport of any solute through soil. Soil diffusive tortuosity (τ) defines the effective diffusion path in soil while dispersivity (λ) quantifies the spread in flow velocity of a solute in soil. Few studies are available where both τ and λ values have been experimentally determined on the same intact soil core. This study acquired a set of 100 diffusive τ values and associated soil properties measured from soils collected from the states of Odisha and West Bengal in eastern India. Estimated τ values ranged from 1.0 to 3.04, covering the porosity (ϕ) range of 0.25 to 0.60. A pedo-transfer function (PTF) was developed to estimate τ. As the PTF predict τ from easy-to-measure soil properties but requires ancillary soil data other than ϕ, we also tried to estimate τ from ϕ alone using the ensemble averaging approach. Seven different analytical expressions for τ-ϕ and seven different ensemble-modeling approaches were examined. Results showed that the Bayesian model averaging method was the best approach. Of 119 different combinations of τ (ϕ) models, three models derived considering packing of square shaped particles, fractal geometry with particles of different sizes, and percolation theory were identified as the best individual models for ensemble modeling. The coefficient of determination (0.67), root-mean-squared error (0.23), and the Akaike information criterion (94.37) values for this ensemble model were better than those when a single model was used. Since both τ and λ_L are properties of the porous media, we reported the relationship between them in this study as well. The λ_L were estimated from laboratory scale transport experiments using undisturbed soil spheres. The dimensionless parameter λ_L / L_s, where L_s is the straight-line system length, follow a logarithmic relationship with τ ($R^2 = 0.87$). Since λ_L is a function of both the geometry of the porous media and the microscopic variation of pore velocity, our result for the first time shows the nature of relationship between pore geometry (as captured by τ) and λ_L values. Such relationships may be built into flow and transport models to have an initial estimate of the λ in soil.

Keywords: Tortuosity, Dispersivity, Diffusion, Porosity