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A Critical Analysis of the Concept of Scale Dependent Macrodispersivity

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Transport by groundwater occurs over the different scales encountered by moving solute plumes. Spreading of plumes is often quantified by the longitudinal macrodispersivity α_L (half the rate of change of the second spatial moment divided by the mean velocity). It was found that generally α_L is scale dependent, increasing with the travel distance L of the plume centroid, stabilizing eventually at a constant value (Fickian regime).

It was surmised in the literature that α_L scales up with travel distance L following a universal scaling law. Attempts to define the scaling law were sursued by several authors (Arya et al, 1988, Neuman, 1990, Xu and Eckstein, 1995, Schulze-Makuch, 2005), by fitting a regression line in the log-log representation of results from an ensemble of field experiment, primarily those experiments included by the compendium of experiments summarized by Gelhar et al, 1992.

Despite concerns raised about universality of scaling laws (e.g., Gelhar, 1992, Anderson, 1991), such relationships are being employed by practitioners for modeling multiscale transport (e.g., Fetter, 1999), because they, presumably, offer a convenient prediction tool, with no need for detailed site characterization. Several attempts were made to provide theoretical justifications for the existence of a universal scaling law (e.g. Neuman, 1990 and 2010, Hunt et al, 2011).

Our study revisited the concept of universal scaling through detailed analyses of field data (including the most recent tracer tests reported in the literature), coupled with a thorough re-evaluation of the reliability of the reported α_L values. Our investigation concludes that transport, and particularly α_L, is formation-specific, and that modeling of transport cannot be relegated to a universal scaling law. Instead, transport requires characterization of aquifer properties, e.g. spatial distribution of hydraulic conductivity, and the use of adequate models.