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Development of a Time-dependent Single-Rate Model and equivalence with MRMT

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Breakthrough curve tailing is a strong indication of non-Fickian mass transfer processes taking place over multiple scales. Yet, Haggerty et al. [2004] showed that in most experimental data it is possible to fit a single rate model provided that the single-rate mass transfer coefficient varies with exposure time. This paper studies the mathematical equivalence between the Multi-Rate Mass Transfer Model (MRMT) and a time-dependent single-rate mass transfer model (t-SRMT). We found that the t-SRMT model can be expressed by means of a memory function that is non-stationary. It was also found that the full behavior of the concentrations using a single time-dependent rate $\omega(t)$ is approximately analogous to that of the MRMT model provided that the equality $\omega(t) = -d \ln g(t)/dt$ holds and the field capacity is properly chosen. This relationship suggests that when the memory function is a power law, $g(t) \sim t^{1-k}$, the equivalent mass transfer coefficient scales as $\omega(t) \sim t^{-1}$, nicely fitting without calibration the estimated mass transfer coefficients compiled by Haggerty2004.