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On the use of power laws to predict solute transport in highly heterogeneous media without fitting

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In spite of decades of efforts by hydrogeologists, fitting of breakthrough curves (BTCs) remains challenging for practical applications. Predicting BTCs tailing is even more complicated, particularly due to the uncertain relationship between mathematical and physical properties of the aquifers. We present a study where different statistical models are adopted to describe heavily tailed BTCs observed during tracer tests in highly heterogeneous aquifers. In particular, different power law models and a lognormal model are used and compared. We show that the selection of a specific power law formulation is critical to derive proper parameters with predictive ability. A power law model without cutoff (PL) results in best-fitted exponents which exceed those obtained from a power law model embedding a cutoff term (PLCO). In the latter, we found that the cutoff rate (λ) is the parameter that best reproduces the persistence of the tailing. The cutoff rate is shown to be inversely correlated to the lognormal scale parameter. The theoretical results are used to interpret the MADE-5 experiment and to predict the ensemble average of a stochastic numerical analysis without invoking any empirical fitting parameter. This prediction is only possible when one specific power law model (PLCO) is selected; the other (PL) fails to describe the same experiment using the same entry slope. The analysis shed new lights into the possibility of using effective modeling analysis based on power law like formulations, in particular those models relying on memory like functions to describe transport in highly heterogeneous porous media.