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Taylor Dispersion: Evolution from the Initial Condition

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After nearly 65 years of research on Taylor dispersion and literally thousands of papers on the subject, it is reasonable to ask if there is anything interesting left to be said about it. However, there still remains one outstanding problem in Taylor dispersion theory that has resisted a very satisfactory theoretical description. This is the problem of the relaxation of the initial condition at so-called "early" times in the Taylor dispersion process. Although a number of methods have been proposed, the constraints on the results are usually quite severe (e.g., asymptotic expansions that are only valid for exceptionally small times, or formulations that apply only to particularly simple configurations).

In this talk, we will discuss some of the history of this problem, and recent results that have been obtained by our group for describing the full range of the transport process from early to asymptotically-long times. Our approach is based in conventional PDE theory, and a somewhat unconventional approach to averaging. In particular, we derive an effective mass balance evolution equation not scale invariant upon averaging. The averaged equation contains an exponentially decaying (in time) source term that does not appear in the original microscale balance. The role of this source term is to account for the relaxation of the initial condition by redistributing mass within the domain (hence, the integral of the source term over the entire domain is zero). This leads to a final result that is able to represent spatially non-symmetric distributions of the average concentration at early times, and approaches the conventional Taylor-Aris result at asymptotic times. We compare the results of our upscaled representation with those computed from direct numerical simulation at the microscale; good fidelity between the two methods is observed. The approach has interesting applications to other kinds of systems where upscaling in the proximity to specific initial configurations (e.g., reactive transport; ecological dynamics) is important.

References

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