The Effect of Microchannel Geometry on Dispersing Solute Asymmetries

A. Taylor[1], D. Harris[1]

[1]Brown University, Providence, RI, USA

Abstract

Within the field of microfluidics, scientists and engineers have found ways to manipulate flow at the micron scale in order to downsize standard experimental procedures. These techniques boast faster results while consuming less resources. Microfluidic devices can be used for point-of-care diagnostic testing, drug delivery, blood sample analysis, chemical gradient generation, and more. For many of these applications, a thorough understanding of chemical dispersion in laminar flows, where viscous forces dominate, is essential. COMSOL Multiphysics® offers a microfluidics module in which this type of low Reynolds number flow can be studied simply and effectively. We examine the accuracy of such numerical dispersion modeling by benchmarking our results with exact theoretical expressions.

Each of our studies are time-dependent and utilize the "Transport of Diluted Species" physics. An initial Gaussian solute distribution is defined near the inflow boundary. It is programmed to translate via influence of an exact creeping flow solution, which is entered directly using the 'velocity field' parameter. The internal channel walls have imposed no-flux boundary conditions, and the channel exit is defined with an outflow boundary condition. With this computational set-up, we consider both 2D and 2D Axisymmetric channels. Another option for modeling the steady background flow is to use "Creeping Flow" physics from the microfluidics module.

Our COMSOL Multiphysics® simulations confirm a recently uncovered behavior of microchannel flow; that the channel geometry affects the longitudinal asymmetry of dispersing solute plugs during a transitional time scale [1]. One convenient measure of longitudinal asymmetries is skewness. Skewness is the normalized third moment of, in our case, chemical concentration. Solute in a 2D channel or a 3D channel with a low cross-sectional aspect ratio (defined as a/b from Figure 1) will exhibit a negative skewness. Negative skewness implies a sharp front of solute that has a long, trailing tail. Solute in a rectangular channel with a cross-sectional aspect ratio ~1 will have positive skewness, as will a similarly proportioned axisymmetric channel (Figure 1). Positive skewness means the solute is "back-loaded", or has a long tail in front and higher concentrations at the back.

We compared the variance and skewness of chemical concentration from our simulations with corresponding theoretical expressions. By ensuring the simulations were well-defined and properly refining each mesh, we found that the results are in good agreement with the mathematical model and recent experimental results. These results are encouraging

for our future research and give us confidence in data we produce for novel microfluidic systems simulated in COMSOL Multiphysics®.

References:
[1] M. Aminian, F. Bernardi, R. Camassa, D. Harris, R. McLaughlin. How boundaries shape chemical delivery in microfluidics. Science. Vol. 354. No. 6317 (2016): pp. 1252-1256. URL: http://science.sciencemag.org/content/354/6317/1252

Figures used in the abstract

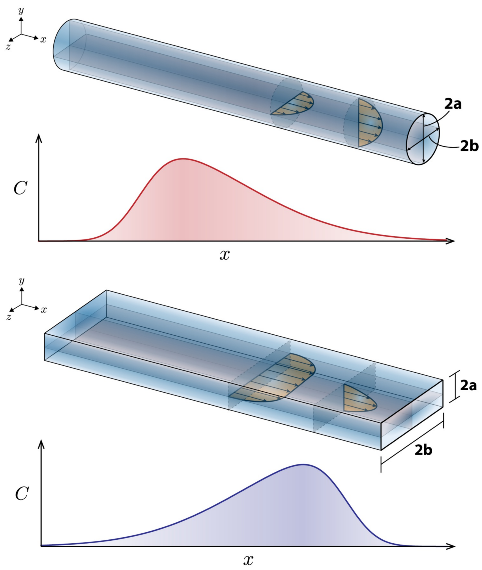

Figure 1: Microchannels with aspect ratios ~1 create solute distributions with positive skewness (top). Aspect ratios below ~0.5 negatively skew the distribution (bottom) [1].