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Water Flux Dynamics in Closed-Loop, Batch-Mode Forward Osmosis Systems

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Abstract

Although several models have been proposed in the literature for the water flux performance in forward osmosis (FO), the fundamental basis, employing the steady-state approximation, remains unchanged. Yet when empirical studies in FO make use of closed-loop, batch systems, both water and solute transport evolve dynamically in time. In this paper, we consider the water flux dynamics and solute kinetics for a closed-loop FO setup, while accounting for the non-linear coupling between solute back diffusion and water transfer as time evolves. This is achieved via a system of non-linear ordinary differential equations that dictates the coupled dynamics of water and solute transport, written in terms of two important dimensionless parameters: the osmotic Peclet number and the solute permeability. Numerical simulations reveal that the solute concentration at the dense layer, interior to the membrane, is non-monotonic in time, thus introducing a new time dependence on the relationship between the water flux and the solute concentration. Model predictions for the time dependency of the water flux is further verified experimentally using sodium chloride as draw solution. These results indicate that caution is required during model fitting procedures employing the classical steady-state formulation in closed-loop FO systems.

Keywords: Forward osmosis; solute back diffusion; closed-loop system; asymmetric membrane; internal concentration polarization.