APPLICATIONS OF POROUS MEDIA THEORY TO MEMBRANE TRANSPORT PHENOMENA

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ABSTRACT

A porous media approach based on the volume averaging theory has been proposed to investigate solute diffusion and ultrafiltration processes associated with hemodialysis using a hollow fiber membrane dialyzer. A general set of macroscopic governing equations has been derived for the three individual phases, namely, the blood phase, dialysate phase and membrane phase. Thus, conservations of mass, momentum and species are considered for blood compartments, dialysate compartments and membranes within a dialyzer to establish a three concentration equation model. These macroscopic equations can be simultaneously solved for the various cases of inlet velocities of blood and dialysate. An analytic expression for the solute clearance was obtained for the one-dimensional case, in which important dimensionless parameters controlling the dialyzer system were identified for the first time.

Subsequently, this membrane transport model based on the porous media theory has been extended to describe the concentration polarization phenomena associated with hollow fiber reverse osmosis desalination systems. A set of the governing equations were derived for the brine, permeate and membrane phases, exploiting a volume averaging approach. These equations based on the membrane transport model originally developed for the dialyzer and extended for the hollow fiber reverse osmosis desalination systems were coupled and reduced to three distinctive first-order ordinary equations in terms of the average velocity, pressure and salt concentration of the brine phase. These equations along with an algebraic equation for the permeate flow rate per unit volume can readily be solved to estimate permeate salinity, permeate flow rate and pressure drop in a hollow fiber reverse osmosis desalination system. Available experimental data and numerical results based on finite difference methods are found to agree well with the present analytical estimates based on the present membrane transport model.