Membrane performance characterization and process prediction in OSN: Challenges, achievements and perspective

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Recent development of new solvent stable materials and continuous improvement of fabrication techniques have permitted the application of membrane filtration to different processes in organic solvent and solvent mixtures. The development of membrane processes usually involves several stages, starting from feasibility tests at membrane scale, passing through fluid dynamics and mass transfer in membrane modules and finishing with large industrial scale process design (Figure 1) [1,2].

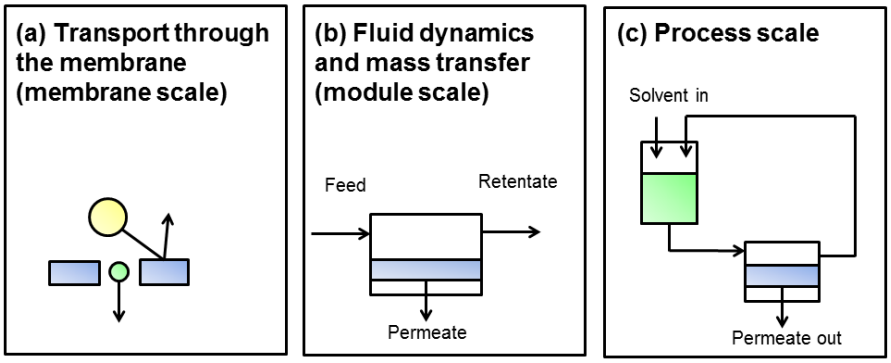


Figure 1. Modelling levels for the development of a membrane process [1].

Substantial research has focused on the description of the transport mechanism through membranes (Figure 1(a)) aiming at: *parameter estimation*, when experimental data for standard solute/solvent systems are available, and it is desired to estimate relevant parameters for as yet uncharacterized systems (Figure 2(a)); and *prediction,* when the model parameters for the solvent-solute are available, and modelling can be applied to describe performance of a different solute/solvent system (Figure 2(c)) [1,3]. Most of these studies have used flat sheet membranes. On the other hand, there is lack of studies on the fluid dynamics and mass transfer characteristics in OSN spiral-wound modules (Figure 1(b)), and attempts to implement fundamental transport models on a process level (Figure 1(c)) are few, and are based on simple, non-predictive membrane transport models.

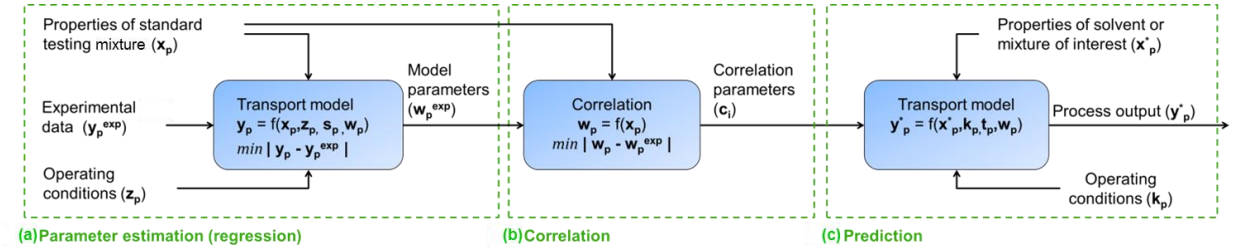


Figure 2. Modelling framework for Organic Solvent Nanofiltration. (a) Parameter estimation (regression); (b) Correlation; (c) Prediction.

This paper reports a systematic comparison of different transport models using selected experimental data for various solutes, solvents and membranes [3]. Solution-diffusion, pore-flow and transient models were used to perform regression of experimental data, and prediction, based on the regressed model parameters. It was observed that solution-diffusion models described permeation through glassy membranes better than pore-flow models, against both positive and negative rejection data (Equation 1).

$$J_i = P_i^{SD}\left[x_i^R - x_i^P \cdot \exp\left(-\frac{v_i}{R \cdot T} \cdot \Delta p\right)\right] \qquad \text{Equation 1}$$

(R = retentate; P = permeate)

$$P_i^{SD} = f\left(\mu_i, \sigma_i, \varepsilon_i, MW_i, \cdot\Delta\delta_i\right) \qquad \text{Equation 2}$$

Afterwards, the permeability coefficient of the classical solution diffusion model (P_i^{SD}) was correlated with the solvent properties (viscosity, surface tension, dielectric constant, molecular weight and Hansen solubility parameter) and the importance of each property was assessed (Equation 2). Finally, the classical solution-diffusion model combined with the film theory was applied to model the performance of different rubber-coated spiral-wound modules (1.8”x12”, 2.5”x40” and 4.0”x40”) under various pressures and retentate flowrates. Correlations for the fluid dynamics and mass transfer in the modules were derived by regression of experimental data. OSN unit operations at membrane and module levels were used in the Aspen Plus process modelling environment (using the OSN Designer [4,5]), to model common batch and steady-state membrane processes.

This paper provides also critical insight and future perspective into the state-of-the-art research, with special emphasis on how transport and process modelling in OSN are advancing and how the technology is leading to the benefits of membrane processing being applied in organic solvents.

References

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