Rigorous mathematical model of foward osmosis membrane modules: a modified spiral-wound, a plate-and-frame, and a hollow fibre

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FO process has been recently spotlighted due to its low energy requirements unlike RO process which requires high external energy for inducing hydraulic pressure. Consequently, FO membrane modules of various geometries manufactured by several major companies have become commercially available. Those commercial membrane modules have much larger size than a lab-scale module; accordingly, it is inevitable to take account of pressure drop which was negligible in a small-sized module. In the present work, mathematical models of various FO membrane modules are developed considering the pressure drop which differs from geometric characteristics. Target modules for modelling are as follows: a modified spiral-wound, a plate-and-frame, and a hollow fibre module. For each module, design parameters are varying with the fixed effective membrane area in order to investigate the effects of pressure drop on the performance and the pumping energy. Thus, the cost of the membrane process can be calculated as the required pumping energy per the product water. Furthermore, the optimal design parameters can be found by applying the developed models.