Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2012.751146

51 (2013) 3604–3627
April

Taylor & Francis
Taylor & Francis Group

Membrane module design and dynamic shear-induced techniques to enhance liquid separation by hollow fiber modules: a review

Xing Yang[a], Rong Wang[a,*], Anthony G. Fane[a], Chuyang Y. Tang[a], I.G. Wenten[b]

[a]*Singapore Membrane Technology Centre, School of Civil & Environmental Engineering, Nanyang Technological University, 639798, Singapore, Singapore*
Tel. +65 6790 5327; Fax: +65 6791 0676; email: rwang@ntu.edu.sg
[b]*Bandung Institute of Technology Bandung, Jalan Ganesha 10, Bandung, 40132, Indonesia*

Received 24 June 2012; Accepted 12 September 2012

ABSTRACT

Membrane-based separation processes have found numerous applications in various industries over the past decades. However, higher energy consumption, lower productivity, and shorter membrane lifespan due to polarization and membrane fouling continue to present severe technical challenges to membrane-based separation. Improved membrane module design and novel hydrodynamics offer strategies to address these challenges. This review focuses on hollow fiber membrane modules which are well suited to membrane contactor separation processes. Attempts to improve membrane module design should begin with a better understanding of the mass transfer in the hollow fiber module; therefore, this review provides a summary of prior studies on the mass transfer models related to both the shell-side and tube-side fluid dynamics. Based on the mass transfer analysis, two types of technique to enhance hollow fiber membrane module performance are discussed: (1) passive enhancement techniques that involve the design and fabrication of effective modules with optimized flow geometry or (2) active enhancement techniques that uses external energy to induce a high shear regime to suppress the undesirable fouling and concentration polarization phenomena. This review covers the progress over the past five years on the most commonly proposed techniques such as bubbling, vibrations, and ultrasound. Both enhancement modes have their advantages and drawbacks. Generally, the passive enhancement techniques offer modest improvement of the system performance, while the active techniques, including bubbling, vibrating, and ultrasound, are capable of providing as high as 3–15 times enhancement of the permeation flux. Fundamentally, the objectives of module design should include the minimization of the cost per amount of mass transferred (energy consumption and module production cost) and the maximization of the system performance through optimizing the flow geometry and operating conditions of the module, scale-up potential, and expansion of niche applications. It is expected that this review can provide inspiration for novel module development.

Keywords: Membrane module design; Passive and active enhancement modes; Mass transfer; Hydrodynamics; Energy efficiency

*Corresponding author.