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Review

Forward osmosis niches in seawater desalination and wastewater reuse

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ABSTRACT

This review focuses on the present status of forward osmosis (FO) niches in two main areas: seawater desalination and wastewater reuse. Specific applications for desalination and impaired-quality water treatment and reuse are described, as well as the benefits, advantages, challenges, costs and knowledge gaps on FO hybrid systems are discussed. FO can play a role as a bridge to integrate upstream and downstream water treatment processes, to reduce the energy consumption of the entire desalination or water recovery and reuse processes, thus achieving a sustainable solution for the water-energy nexus. FO hybrid membrane systems showed to have advantages over traditional membrane process like high pressure reverse osmosis and nanofiltration for desalination and wastewater treatment: (i) chemical storage and feed water systems may be reduced for capital, operational and maintenance cost, (ii) water quality is improved, (iii) reduced process piping costs, (iv) more flexible treatment units, and (v) higher overall sustainability of the desalination and wastewater treatment process. Nevertheless, major challenges make FO systems not yet a commercially viable technology, the most critical being the development of a high flux membrane, capable of maintaining an elevated salt rejection and a reduced internal concentration polarization effect, and the availability of appropriate draw solutions (cost effective and non-toxic), which can be recirculated via an efficient recovery process. This review article highlights the features of hybrid FO systems and specifically provides the state-of-the-art applications in the water industry in a novel classification and based on the latest developments toward scaling up these systems.

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Contents

1. Introduction

1.1. *Increasing need for fresh water along coasts*

Due to the development of coastal regions in many countries, two-fifths of cities with populations of 1 million to 10 million people are located near coastlines (Tibbetts, 2002). Moreover, 14 of the largest 17 cities in the world are situated along coasts (Fig. 1) (Creel, 2003). More than 3 billion people will live under water-scarce or water-stressed conditions by year 2025 (The Barila Group et al., 2009). Since more than 97% of the water in the world is seawater, desalination technologies have the potential to solve the fresh water crisis, particularly in coastal areas. Present conventional desalination technologies such as high pressure reverse osmosis (RO) involve expensive and energy intensive processes. A similar situation is faced when a wastewater effluent is treated with advanced technologies to produce high quality water. Therefore, there is an urgent need for a better technology that can recover water from impaired sources, providing an economic supply of fresh water to the increasing global human population.

1.2. *Current membrane systems in the water industry: reverse osmosis*

Desalination is a general term for the process of removing salt from water to produce fresh water. Fresh water is defined as containing less than 1000 mg L^{-1} of salts or total dissolved solids (TDS) (Miller and Evans, 2006). The most common membrane desalination process in the world is reverse osmosis (RO) (Fritzmann et al., 2007). It is based on a property of certain polymers called semi-permeability, in which the polymer membrane has high permeability to water, but not for dissolved solids (i.e. salts). By applying a pressure difference across the membrane higher than the osmotic pressure of the feed water (i.e., seawater), fresh water is forced to permeate through the membrane. Common operating pressures for seawater desalination systems range between 55 and

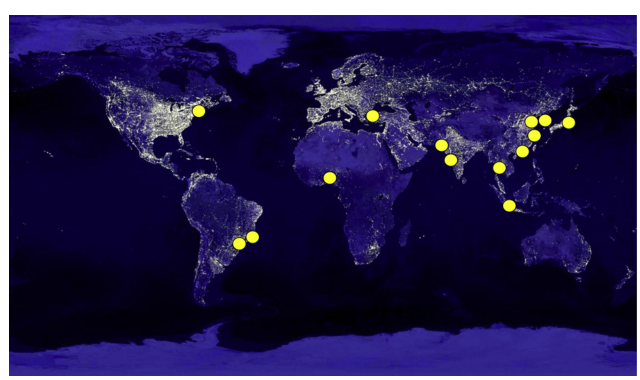

Fig. 1 – Fourteen of the world's largest cities are located along the coast (indicated in yellow marker), which translates into an opportunity to economically integrate drinking water and wastewater management, especially in water-stressed areas (Creel, 2003) (Image adapted from NASA 2000). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)