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Desalination 247 (2009) 148–161
DESALINATION
www.elsevier.com/locate/desal

Effect of solution chemistry on the surface property of reverse osmosis membranes under seawater conditions

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Received 13 November 2008; revised 17 December 2008; accepted 24 December 2008

Abstract

Recent studies have shown that the rougher, less negatively charged, and more hydrophobic membranes are prone to organic fouling. These surface characteristics of RO membranes, however, have been usually determined at very low TDS conditions, while seawater contains ten to thousand times more TDS than surface and even brackish waters. In this study, three aromatic polyamide thin-film composite (TFC) RO membranes were characterized for chemical and physical properties. Membrane characterization was performed under both the low (i.e., 10 mg/L) and high (i.e., 35,000 mg/L) TDS conditions to see how these surface characteristics are affected by seawater-level TDS. Results showed that both the chemical and physical surface properties were altered significantly under the high TDS condition with becoming more favorable to membrane fouling, namely, less negatively charged, more hydrophobic, and rougher. Mechanisms responsible for these changes such as charge screening and osmotic swelling are delineated. The way of changing in surface characteristics under the high TDS condition was substantially different with respect to the surface characteristics determined at the low TDS condition. It was confirmed that the chemical and physical properties were interrelated and, thus, variations in chemical properties with respect to the solution chemistry applied led to changes in physical properties and vice versa.

Keywords: Membrane surface characterization; Seawater TDS; RO membranes; Surface charge; Hydrophobicity; Surface roughness

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Presented at the 2nd joint workshop between the Center for Seawater Desalination Plant and the European Desalination Society, Gwangju Institute of Science and Technology, Korea, October 8–9, 2008.

0011-9164/09/$– See front matter
doi:10.1016/j.desal.2008.12.020

1. Introduction

Desalination based on reverse osmosis (RO) is exponentially being in the spotlight of treatment alternatives to overcome worldwide water scarcity and the lack of safe water. Although RO desalination is currently the most promising technology, there are still several challenges to be solved for efficient application. Among the major challenges of RO desalination is membrane fouling. There are several factors affecting membrane fouling such as foulant properties, membrane characteristics, and feed water chemistries [1–3]. Among these factors, membrane characteristics are first concerned practically since the others are rather natural factors with bearing difficulties in handling. Systematic and rigorous characterization of RO membranes could give useful insight into the better understanding of fouling phenomena, leading to an efficient control of membrane fouling.

Surface characteristics are of paramount importance in RO membranes since polymeric TFC RO membranes are considered to be non-porous and, thus, the adhesion of foulants on the non-porous membrane surface is a key fouling mechanism [4,5]. Important membrane surface characteristics affecting the foulant adhesion on the membrane surface are surface roughness, charge, and hydrophobicity. Several researches have been performed to investigate RO membrane surface characteristics as well as find out the relationship between the membrane surface characteristics and the rate and extent of membrane fouling [6,7]. It has been shown that RO membrane surface roughness plays an important role in colloidal fouling [8,9]. The RO membranes with rougher surface were prone to colloidal fouling as the valleys created by the rough surface produced wells of low interaction energy in which colloidal particles preferentially deposited [10]. In case of surface charge, it has been known that RO membranes with negative surface charge exhibited low fouling tendency. Most foulants were negatively charged and, thus, the electrostatic repulsion between evenly charged foulants and membrane surface prevented foulant adhesion [11–13]. It has been also known that hydrophobic membranes more severely suffered from membrane fouling than hydrophilic membranes due to the strong hydrophobic interaction, which could allow multi-fouling layers on the membrane surface [14–16]. Therefore, the smoother, more negatively charged, and less hydrophobic membranes have been considered to be enviable for reducing organic fouling of RO membranes.

The most eminent feature of RO desalination compared with other membrane-based water treatments such as drinking water treatment, wastewater reuse, and brackish water treatment is that seawater contains ten to thousand times higher TDS than surface, waste, and even brackish waters. Most previous researches dealing with surface characterization of RO membranes, however, have been carried out under very low TDS conditions significantly lower than seawater TDS. Therefore, there is a possibility of misunderstanding during the analyses of RO membrane surface characteristics since the aforementioned characteristics (i.e., roughness, charge, and hydrophobicity) may change upon high TDS environment. The altered surface characteristics due to high TDS conditions could affect foulant–membrane interactions resulting in subsequent alteration in the rate and extent of membrane fouling. Therefore, it is of paramount importance to determine RO membrane surface characteristics at seawater-level TDS condition as well as investigate how these altered characteristics affect the rate and extent of membrane fouling.

In this study, the widely used commercial RO membranes were characterized under two substantially different TDS levels of 10 and