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A fouling model for simulating long-term performance of SWRO desalination process

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ABSTRACT

A fouling model for the seawater reverse osmosis (SWRO) process is required to propose an appropriate strategy for membrane maintenance (i.e., membrane cleaning and replacement). In this study, a fouling model that considered the concentration polarization was properly developed to simulate the long-term performance of the SWRO process based on models from the literature. The model was practically applied to one-year operation data obtained from the Fujairah SWRO desalination plant with parameter estimation, and good agreement between the measured data and simulated results was obtained for both the rejection and recovery rates. Compared to an integrated model consisting of two models from the literature, the fouling model proposed in this study showed reliable performance for membrane fouling such as the increase in the permeate TDS concentration according to operating time. In addition, simulations for membrane maintenance were conducted based on the variation in membrane resistance, which reflects the fouling state of the membrane. These revealed that the rearrangement of membranes is not significantly effective without cleaning the fouled membrane. Instead, a partial replacement of membranes can be an effective maintenance scheme to increase the recovery rate. Accordingly, the results of the study presented here can be used to save operation and maintenance (O&M) costs in SWRO plants through the optimized management of fouled membranes.

1. Introduction

Reverse osmosis (RO) is a pressure-driven separation process that is capable of passing water while rejecting solutes (i.e., salts or low molecular weight organics) [1]. The performance of the RO process is directly and/or indirectly influenced by several factors, including the trans-membrane pressure (TMP), concentration polarization (CP), membrane fouling, water quality characteristics, and specific membrane characteristics [2]. Among these factors, membrane fouling refers to the deposition or adsorption of particles contained in the feed water and has negative impacts on filtration performance such as permeate flux decline under certain operating conditions or a TMP increase for producing the desired permeate flux [3]. In spite of pretreatment processes such as dual media filtration and UF/NF membrane filtration, membrane fouling inevitably occurs in the RO membrane process because of the dissolved organic matter and small suspended colloidal particles that still remain in the pretreated feed water. Several researches have been carried out to reveal fouling phenomena, predict fouling development, and prevent fouling formation [3–7]. However, membrane fouling has not been fully controllable and predictable until now, because it is affected by the complex composition of seawater (i.e., inorganic/organic, colloidal, and biological foulants) and includes several fouling mechanisms (e.g., scale, cake, and bio-film formations), leading to a deterioration in the RO performance (i.e., decreases in permeate flux and salt rejection) [2,3].

In order to consider membrane fouling, a resistance-in-series model, which is a phenomenological approach to membrane mass transport, has been widely used by considering membrane resistance [7,8]. Before applying the model to an RO membrane, it has been used to simulate the performance of an ultrafiltration (UF) process [3]. The membrane resistance in the model is used to determine the flux of the product water instead of the water permeability coefficient in most common RO transport models and can be divided into two parts: the intrinsic membrane resistance and the fouling layer resistances [9]. While the intrinsic

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