Seawater-driven forward osmosis for direct treatment of municipal wastewater

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Abstract

Direct treatment of municipal wastewater by forward osmosis (FO) process was evaluated in terms of water flux decline, reverse salt diffusion, pollutants rejection and concentration efficiency by using seawater as the draw solution. It was found that when operating in PRO mode (active layer facing the draw solution), although the FO membrane exhibited higher osmotic water flux, more severe flux decline and reverse salt diffusion was also observed due to the more severe fouling of pollutants in the membrane support layer and accompanied fouling enhanced concentration polarization. In addition, although the water flux decline was shown to be lower for the FO mode (active layer facing the feed solution), irreversible membrane fouling was identified in both PRO and FO modes as the water flux cannot be restored to the initial value by physical flushing, highlighting the necessity of chemical cleaning in long-term operation. During the 7 cycles of filtration conducted in the experiments, the FO membrane exhibited considerably high rejection for TOC, COD, TP and NH_4^+-N present in the wastewater. By optimizing the volume ratio of seawater draw solution/wastewater feed solution, a concentration factor of 3.1 and 3.7 was obtained for the FO and PRO modes, respectively. The results demonstrated the validity of the FO process for direct treatment of municipal wastewater by using seawater as the draw solution, while facilitating the subsequent utilization of concentrated wastewater for bioenergy production, which may have special implications for the coastline areas.

Keywords: forward osmosis (FO); municipal wastewater; seawater; membrane fouling

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1. INTRODUCTION

Environmental pollution and water resource shortage have become two of the most significant problems that faced on a global scale. High pressure driven membrane processes such as reverse osmosis (RO) and nanofiltration (NF) can produce cleaner and safer water from non-conventional water resources, including desalination of seawater and saline water, reuse of treated wastewater, purification of impacted surface water, etc. (Do 2012, Wu 2013, Zheng 2014). However, the efficiency and sustainable operation of RO and NF has been limited by the considerable energy consumption and severe membrane fouling induced by the high hydraulic pressure (Boo 2012, Menachem Elimelech and Phillip 2011, Motsa 2014).

Recently, forward osmosis (FO) has been emerging as an innovative platform technology to address the above-mentioned issues (Kong 2015, Liu 2013, Shaffer 2015, Zhang 2015, Zhao 2015). Instead of the applied hydraulic pressure, FO employs the osmosis pressure difference between the feed solution and draw solution as the driving force to induce water transport across a semipermeable membrane. As a result, the FO technology exhibits several distinguished advantages such as low energy consumption, low fouling propensity, and ease of cleaning (Razmjou 2013, Wang 2015, Widjojo 2013, Xue 2015, Zhang 2012a). And the FO process has shown excellent application potentials in various fields, such as seawater/saline water desalination, oil wastewater treatment, shale gas produced water reclamation, landfill leachate treatment, osmosis pressure power generation, etc.(Dong 2014, Phuntsho 2013, Qi 2015, Shaffer 2013, She 2012b, Valladares Linares 2012).

On the other hand, along with the increasingly growing demand for clean water all over the world, there is also the corresponding increase in the amount of wastewater needed to be properly treated (Valladares Linares 2013). At present, the treatment of municipal wastewater is mainly performed through aerobic biological processes where intensive air bubbling is required. Two problems are associated with these processes: (1) relatively high energy consumption is required for these processes, it is estimated that 0.4-2.1 kW/h of electricity power will be demanded for treating 1 m^3 of wastewater (Zhang 2014b); (2) there are still some kind of pollutants present in the wastewater secondary effluents, such as refractory organics, nitrogen, phosphorous, heavy metals, etc., which may still cause the contamination of receiving water bodies (Valladares Linares 2013).

It is reported that today more than 3 billion people live along the coastlines and this number is continuously growing (Valladares Linares 2013). As a result, there is an ever-increasing pressure for the sufficient treatment of municipal wastewater to meet the discharge regulation for protection of marine environment. Therefore, it might be a fantastic idea if the FO process can be employed for direct and effective wastewater treatment by using seawater as the natural, abundant and costless draw solution, as suggested by Linares et al. (Valladares Linares 2013) and Zhang et al. (Zhang 2014b). In which, the diluted seawater can be discharged back to the ocean, while the concentrated wastewater can be used for biogas production through anaerobic digestion.

In this work, the performance of a commercial cellulose triacetate (CTA) FO membrane for the treatment of municipal wastewater was evaluated with real municipal