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OIL SANDS PROCESS-AFFECTED WATER (OSPW) MANAGEMENT USING BASAL DEPRESSURIZATION WATER (BDW) IN FORWARD OSMOSIS (FO)

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Abstract: Forward osmosis (FO) is a promising membrane technology with various potential advantages including low energy input, high rejection efficiency, and high fouling reversibility. The feasibility of FO process has been examined previously in water and wastewater treatment, especially for oil and gas wastewaters. In the current study, to reduce the cost and energy input, FO was proposed to desalinate oil sands process-affected water (OSPW), using on-site waste basal depressurization water (BDW) as the draw solution. The results of long-term desalination experiments did not provide a clear difference between two operating conditions (FO and PRO mode) on membrane fouling because of the comparatively low water flux. Membrane cleaning research indicated that osmotic backwash using clean water efficiently recovered the initial water flux. High rejection rate (> 90%) of inorganic and organic species was achieved, especially, the rejection of naphthenic acids (NAs) reached above 94%. Meanwhile, the volume of OSPW was decreased >40%, corresponding to 1.4 times dilution of BDW in 24 hours. The obtained high rejection rates indicated the potential of safe discharge and/or reuse the diluted BDW after a sufficient processing period.

1 Introduction

Similar to other petroleum refinery and hydraulic fracturing wastewaters, oil sands process affected water (OSPW) contains both dissolved inorganic (i.e., heavy metals) and organic compounds (i.e., naphthenic acids; NAs) which are acute and chronic toxic to various aquatic organisms [1, 2]. To date, tailing ponds cover an area of 180 square kilometers and the surface is increasing yearly as new ponds are being developed. Recent research has shown great interests in an emerging membrane desalination technology — forward osmosis (FO) [3]. FO process requires less or no extra hydraulic pressure, which minimizes the membrane fouling potential and reduces the energy input. However, the selection of proper draw solution was is still under investigation from the perspective of cost reduction and recycle and/or safe discharge [4]. In the current study, we proposed a novel concept of using basal depressurization water (BDW), one of on-site brackish wastewaters, to drive OSPW desalination through semi-permeable membrane. BDW, the depressurized groundwater, was produced in open mining to control surface runoff and seepage water accumulation [5]. It is hypothesized that by employing FO process, the concentration of OSPW and dilution of BDW could be achieved at one process. Additionally, considering complex water characteristics of OSPW, it is expected that the membrane facing OSPW is more tended to foul.

2 Materials and methods

The schematic of FO system is shown in Figure 1. The commercial available cellulose triacetate (CTA) FO membrane was placed in a SEPA FO cell without using feed spacer or permeate carrier. Two speed-variable peristaltic pumps were applied to control the crossflow velocities on each side of the membrane. A digital balance (Scout Pro, Ohaus Corp., Parsippany, NJ, USA) connected to a computer was used to monitor the weight change of the draw solution. Membrane orientations including active layer facing the feed solution (FO mode) and active layer facing draw solution (PRO mode) were tested as an important factor affecting the membrane performance (i.e., internal concentration polarization).

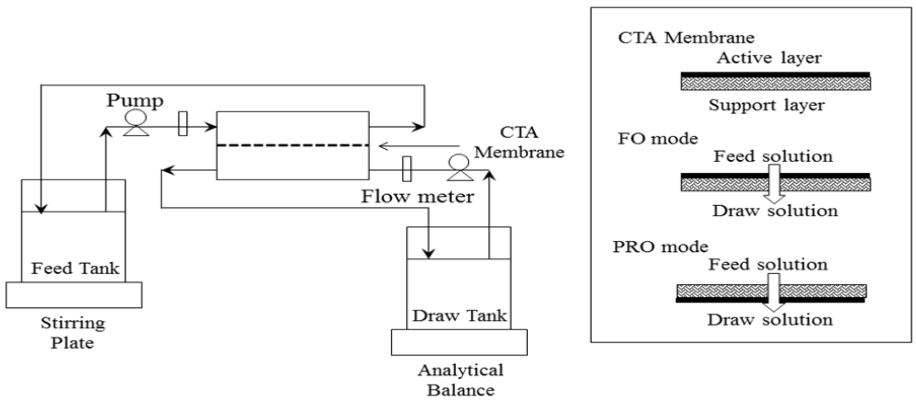

Figure 1: Schematic of FO system set-up.

3 Results

Figure 2 exhibits the water flux profiles under two operating modes. In FO mode, the initial water flux (1st day) started from 2.60 L/m² hr, which was lower than the initial water flux (2.95 L/m² hr) found in PRO mode. The difference of initial water flux on the two membrane orientation could be explained by the enhancement of internal concentration polarization (ICP) when BDW was directly contacting with the support layer (FO mode). The initial fluxes sharply declined to 1.92 L/m² hr (10.4%) and 2.57 (12.9%) observed on 2nd day in FO and PRO mode, respectively, and steady decreased afterwards. Immediate membrane pore blocking or scaling in the first 24 hours might be the reason caused the sharp drop of initial water flux. After 2nd day, foulants kept accumulating, thereby gradually decreasing the initial water fluxes in the following days. On 7th day, the initial water fluxes were reduced 36% in FO and 28% in PRO mode, respectively. Due to the comparatively weak driving force between OSPW and BDW, our results could not distinguish the fouling propensity of OSPW on the two membrane orientations because ICP phenomenon was more influential than membrane fouling under the low water flux condition throughout the experiment.

SEM images of the used membrane coupons further confirmed our previous assumptions. Figure 3 shows the SEM images of the active and support layers after 7-day desalination. In FO mode (Figure 3 a and b), scattered or clustered white foulants were observed on the side facing with OSPW while no surface foulants were found on the support layer against BDW. The same with FO mode, no fouling or precipitation were seen on the active layer surface against BDW but some accumulated precipitations were found surrounded by the pores on the support layer against OSPW in PRO mode. Due to the less smooth structure, particles or foulants were comparatively easier to deposit on the support layer and those smaller size foulants could flow into the inner pores, resulting in a continuous drop of permeate flux.

The overall salt rejection was above 90.0% and BDW was diluted approximately 1.5 times calculated by the conductivity before and after desalination in both modes (diluted BDW in FO mode: 12.9±0.1 mS/cm and in PRO mode: 12.2±0.1 mS/cm). As BDW diluted, chemical oxygen demand (COD) concentrations in BDW were decreased from 167.3 to 108 and 97.5 mg/L, respectively and total organic carbon (TOC) concentration was reduced from 12.9 to 6.13 and 5.8 mg/L in FO and PRO modes, respectively. The organic rejection quantified through NAs, TOC, and COD was above 94%.

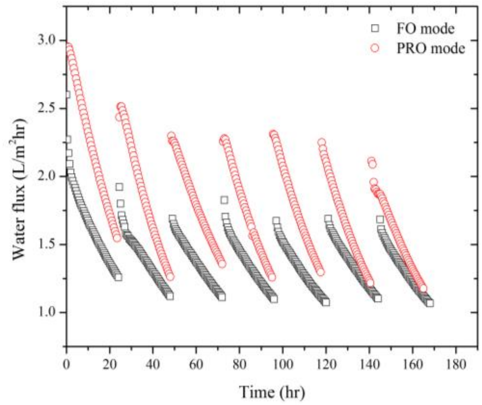

Figure 2： Results of 7-day OSPW desalination test using BDW as draw solution. The experiment was conducted using BDW as draw solution and natural settled OSPW as the feed solution. The crossflow velocity was maintained at 14 cm/s and two operating modes were tested.

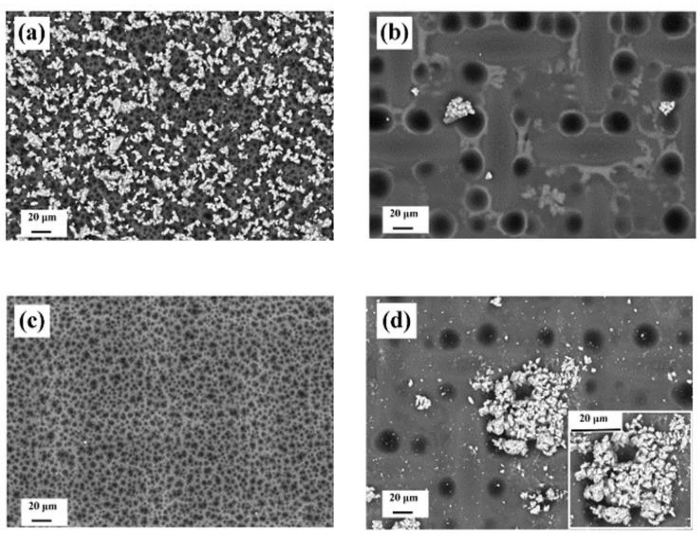

Figure 3： SEM images after 7 days desalination. FO mode (a) active layer (b) support layer. PRO mode: (c) active layer (d) support layer

4 Conclusion and recommendation

The feasibility of using BDW as the draw solution for OSPW desalination was confirmed by our investigation. The experimental results indicated that more than 40% volume of OSPW was reduced while the TDS concentration in BDW was diluted 1.4 times correspondingly. However, to apply it in practice, two main challenges need to be addressed: 1. Low driving force: BDW is less concentrated compared to other highly brackish water, to increase water flux, larger membrane area (i.e., using hollow fiber FO membrane) is recommended. 2. Membrane fouling: The impact of fouling can be diminished by carrying out pre-treatments (i.e., microfiltration, coagulation and flocculation) and optimizing operational condition (i.e., high crossflow velocity, using membrane spacer). By optimizing this process, it is expected that the environmental impact associated with large quantity of OSPW can be alleviated. The concentrated OSPW can be sent for further specific treatments, for example, advanced oxidation and reverse osmosis. The diluted BDW containing less total dissolved solids (TDS) and organic components can be used as process water (i.e., boiler feed) in oil sands industry after advanced treatment, for example, reverse osmosis. This process introduced both a cost and energy effective water management concept that not only aims to OSPW treatment but also the management of other process waters.

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