Journal of Water Process Engineering 25 (2018) 22–27

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Effect of pressure on desalination of MBR effluents with high salinity by using NF and RO processes for reuse in irrigation

M.C. Hacıfazlıoğlu[a,1], H.R. Tomasini[a,b], N. Kabay[a,*], L. Bertin[b], T.Ö. Pek[c], M. Kitiş[d], N. Yiğit[d], M. Yüksel[a]

[a] Ege University, Chemical Engineering Department, Faculty of Engineering, Izmir, Turkey
[b] Alma Mater Studiorum University of Bologna, Chemical Engineering Department, Bologna, 40126, Italy
[c] ITOB-OSB, Tekeli-Menderes, Izmir, Turkey
[d] Süleyman Demirel University, Environmental Engineering Department, Faculty of Engineering, Isparta, Turkey

ARTICLE INFO

Keywords:
Agricultural irrigation
Membrane processes
Nanofiltration (NF)
Reverse osmosis (RO)
Wastewater reclamation
Water reuse

ABSTRACT

Clean water sources are quickly depleted since the industrial revolution due to climate change and overpopulation. Use of potable water for agricultural irrigation is under imminent threat. Therefore, it is important to obtain irrigation water from alternative sources such as industrial wastewaters. On the other hand, industrial wastewaters have to be treated well otherwise they can pollute the environment and decrease the irrigation potential of soil. Membrane bioreactor (MBR) effluents of industrial wastewaters have a great potential to be used in agricultural irrigation. In this study, the permeates of NF270 and BW30-RO membranes were produced from MBR effluent discharged from Wastewater Treatment Plant of ITOB Organized Industrial Zone, Menderes, Izmir. They were evaluated for their reuse in agricultural irrigation. While doing this evaluation, effect of operating pressure on water quality was also investigated. It was found that the RO permeate is not suitable to reuse in irrigation. On the other hand, the NF permeate could be suitable for medium-salinity tolerant plants.

1. Introduction

Climate change, industrialization and overpopulation deplete fresh water sources, especially in arid or semi-arid regions such as North Africa, the Middle East, Australia [1]. Agricultural demand for potable water is stated more than 70% of water withdrawal by Food and Agricultural Organization (FAO) in 2016 [2]. The use of wastewater for agricultural irrigation may decrease the amount of used potable water yet it would increase salinity, damage soil quality and crop development [3]. Wastewater reclamation may be a good choice for this problem.

Membrane bioreactor (MBR) is a process combining biological treatment with membrane filtration in a bioreactor. It has superiority over conventional activated sludge system (CASS) since it does not include sedimentation unit and gives less sludge production, higher total suspended solid (TSS) rejection and smaller footprint [4]. Since MBR effluent quality is higher than CASS effluent, it can be evaluated for the irrigation. Nanofiltration (NF) and reverse osmosis (RO) processes can be used as post-treatment after MBR process to produce water for agricultural irrigation.

It is suggested that pressure-driven membrane processes can be used to treat secondary effluent of industrial wastewater in order to reuse it in agricultural irrigation since these membranes are capable of removing various monovalent and divalent ions from the solution and therefore can reduce salinity in water greatly. There are various studies on the application of NF and RO processes for reclaiming wastewater in order to reuse in agricultural irrigation [5–7]. Bunani et al. [6] experimented with AK-BWRO and AK-SWRO membranes for municipal wastewater reclamation. Their findings indicated a certain blend ratio of the secondary treated municipal effluent and RO permeate can be used for agricultural irrigation. Shanmuganathan et al. [5] also suggested a blend of NF and RO permeates when they worked with NP-010, NP-030 NF and WC-RO membranes.

RO process is cost effective since phase change does not occur unlike thermal treatment processes [8]. RO process is the most-widely used desalination method for brackish water and seawater today and applications of the RO process are various, mostly focused on purification and concentration. RO process is also used as a pre-treatment process for production of high pressure boiler feed water or ultrapure water, applied before electrodeionization (EDI) or ion-exchange [9].

* Corresponding author.
E-mail address: nalan.kabay@ege.edu.tr (N. Kabay).
[1] Present address: Istanbul Technical University, Chemical Engineering Department, Turkey.

https://doi.org/10.1016/j.jwpe.2018.06.001
Received 2 March 2018; Received in revised form 17 May 2018; Accepted 3 June 2018

Nomenclature

A (m^2)	Membrane area
C_f	Feed parameter value
C_p	Permeate parameter value
C, C ($L/m^2 h$)	Concentrate stream, concentrate flux
F, F ($L/m^2 h$)	MBR effluent, MBR effluent flux
P, P ($L/m^2 h$)	Permeate stream, permeate flux
R (%)	Rejection of any parameter
V_c (L/min)	Concentrate flowrate
V_p (L/min)	Permeate flowrate
WR (%)	Water recovery

Main model of the mass transport in a NF membrane is represented by Donnan steric pore model and dielectric exclusion [10]. Since pores are not media for solute transfer in dense membranes such as RO membranes, main causes of mass transfer for RO membranes are size exclusion and charge exclusion [11]. This situation causes a significant flux difference between NF and RO membranes even though the quality of permeate is better for RO.

Dependency of permeate flux on the applied pressure for solution-diffusion transport mechanism is shown by Eq. (1) (Shenvi, 2015).

$$J_P = L_P * (\Delta P - \Delta\pi) \tag{1}$$

where J_P is the permeate flux, L_p is the water permeability (a specific characteristic of a membrane), ΔP is the pressure difference between two sides of membrane and $\Delta\pi$ is the osmotic pressure difference between feed and permeate solutions.

Although increasing pressure increases irreversible fouling due to compression of foulants [12], increased flux and better salt rejection are often desired.

The scope of this study was to investigate the effects of pressure on the produced permeate from NF and RO membranes and evaluation of the product water for reuse in agricultural irrigation.

2. Methods

2.1. System configurations and experiments

BW30-RO and NF270 membranes were used for this experimental study. Properties of these membranes are given in Table 1.

BW30-RO, product of Dow Filmtec™ is a polyamide thin film RO membrane and provides a high rejection stability even with high TDS in water. The NF membrane NF270 is also produced by Dow Filmtec™. MWCO of NF270 membrane is given between 200–400 Da. Average MWCO of NF270 is also determined by Rohani et al. as 330 Da ± 4 and by Kelewou et al. as 257 Da ± 15 [13,14].

Studies were performed for a period of 4 h under the applied pressure of 10 and 20 bar for NF270, 20 and 30 bar for BW30-RO.

Permeate and feed samples were taken at each hour and analyzed for parameters related with irrigation quality. Concentrate and permeate flow rates are recorded in each half hour. Average results were used to obtain more reliable results.

Experiments were performed in a container laboratory where a mini pilot-scale membrane test system was placed in the wastewater treatment plant of ITOB Organized Industrial Zone at Menderes, Izmir, Turkey (Fig. 1).

Flow scheme of the membrane test system was given in Fig. 2.

2.2. Characteristics of the feed water

MBR effluent of the wastewater treatment plant of ITOB Organized Industrial Zone located in Menderes, Izmir (Turkey) was used as the feed solution for NF and RO membranes. After the treatment of industrial wastewater with MBR process as a secondary treatment, MBR effluent stream was collected in a 500 L of storage tank. The characteristics of the MBR effluent were given in Table 2.

2.3. Calculation of performance parameters

Water recovery is calculated for each measurement of permeate and concentrate fluxes by using Eq. (2).

$$WR\,(\%) = \frac{J_P\,(\frac{L}{m^2 . h})}{J_F\,(\frac{L}{m^2 . h})} \tag{2}$$

Where WR is the water recovery and the feed flux (J_F) is the sum of permeate flux (J_P) and concentrate flux (J_C). Permeate flux is experimentally calculated by using Eq. (3).

$$J_P\,(\frac{L}{m^2.\,h}) = \frac{Q_p\,(\frac{L}{min})}{A\,(m^2)} * \frac{60\,min}{1\,h} \tag{3}$$

Where Q_p is the permeate flow rate and A is the active membrane area (2.6 m^2). The concentrate flux is also calculated in the same way; by using V_c (concentrate flow rate) instead of V_p.

All permeate fluxes are normalized at 25 °C by using Eq. (4).

$$J_{P_{adj}} = \frac{J_P}{1.03^{(T-25)}} \tag{4}$$

Where $J_{P\ adj}$ is the adjusted flux normalized at 25 °C and T is temperature of permeate sample at which the tests are performed [15].

Observed rejection of any parameter is calculated by using Eq. (5).

$$R(\%) = \frac{C_f - C_p}{C_f} * 100\% \tag{5}$$

Where R is the observed rejection, C_f is the parameter value in the membrane feed stream and C_p is the parameter value in the permeate stream. Average rejections were calculated from average compositions of permeates and feed streams.

Sodium hazard is the effect of sodium ion on soil hydraulic properties, which can be identified by sodium adsorption ratio (SAR) factor and its calculation method is given in Eq. (6) [16]. SAR is used to compare the effect of sodium concentration of soil permeability by comparing it with divalent cation concentrations.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}] + [Mg^{2+}]}{2}}} \tag{6}$$

Potassium adsorption ratio (PAR) is a dimensionless parameter similar to SAR that shows the effect of potassium instead of sodium and it is calculated with the formula given in Eq. (7). Though there is no agreement of safe PAR value, water with a maximum PAR of 5 seems suitable to use in irrigation. All concentration units for SAR and PAR calculation are meq/L [17].

Table 1
Membrane properties (From Dow Datasheet for BW-30 RO and NF-270 membranes).

Membrane	Active Membrane Area (m^2)	Salt Removal (%)	Max Temperature (°C)	Max Pressure (bar)	pH Interval
BW30	2.6	99.5[a]	50	41	2-11
NF270	2.6	97.0[b]	45	41	2-11

[a] NaCl salt removal.
[b] $MgSO_4$ salt removal.