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Energy Generation from Static Water Head Developed By Forward Osmosis

Adel A. Al-Hemiri, Ghazwan A. Mohammed and Ghazi F. Naser
Department of Chemical Engineering, Baghdad University, Baghdad, Iraq

In this work, the possibility of utilizing osmosis phenomenon to produce energy as a type of the renewable energy using Thin Film Composite Ultra Low Pressure membrane TFC-ULP was studied. Where by forward osmosis water passes through the membrane toward the concentrated brine solution, this will lead to raise the head of the high brine solution. This developed static head may be used to produce energy. The aim of the present work is to study the static head developed and the flux on the high brine water solution side when using forward and reverse osmosis membranes for an initial concentration range from 35-300 g/l for each type of membrane used at room temperature and pressure conditions, and finally calculating the maximum possible power generated from developed static head.

Introduction

Osmosis a physical phenomenon extensively studied by scientists in various disciplines of science and engineering. Early researchers studied the mechanism of osmosis through natural materials, and from the 1960s, special attention was given to osmosis through synthetic materials. Osmotically driven membrane processes utilize an osmotic pressure difference, which is generated when a semi-permeable membrane separates a dilute feed solution from a more concentrated draw solution, to drive the permeation of water from the feed solution to the draw solution. These processes have the potential to sustainable produce clean drinking water or electric power [1]. Forward osmosis (FO), a subset of osmotically driven membrane processes is appealing because it requires no applied hydraulic pressure and has a low membrane fouling propensity [2]. Because of these benefits, FO is attracting attention as a new technology to augment water supplies using non-traditional sources. The potential of this technology was demonstrated in a variety of applications, such as desalination [3, 4], wastewater reclamation [5, 6], industrial wastewater treatment [7], brine concentration [8], osmotic membrane bioreactors [9], liquid food processing [10, 11], and protein concentration [12]. Renewable energy can be extracted wherever two streams of different salinity or different chemical potential meet. Considering that the salinity of seawater yields osmotic pressures of approximately 2.7MPa and that the osmotic pressure of river water is relatively insignificant, a large portion of the 2.7MPa can be used for power generation. The Pressure-Retarded

Osmosis (PRO) is one method that can be used to realize this energy. PRO is preferred for Osmotic hydropower generation and is a similar phenomenon to FO but with applying a pressure on the brine solution side lower than its osmotic pressure, so that PRO will act in conditions between those of FO and RO. PRO for power generation has been continuously studied by Loeb and co-workers [13]. Additionally intensive studies funded by the European union with the main objective being to develop membranes for PRO power that have a production capacity equivalent to at least 4 W/m² [14].

Experimental Section

Studied Variables In the present work the variables taken into consideration are classified into categories according to system arrangements made. The arrangements are: *type of membrane*, FO and RO membranes and the *effect of initial concentration* of the brine solution in the brine solution side. 35,100,165.230 and 300 g / l.

Experimental Apparatus. The apparatus consists of the following parts: (1) Two glass vessels type QVF 15 cm in diameter with 3.5 l capacity. One vessel contains the brine solution and the other contains water. (2) Two membranes type RO and FO. One of the membranes is placed between the two glass vessels; the active layer will face the vessel holding the brine solution. The glass vessels and the membrane are assembled with two flanges and a silicone seal. (3) A glass pipe type QVF with a length of 2m and diameter of 1.8 cm is connected on the brine solution vessel to measure the hydraulic head. (4) A glass L shaped fitting type QVF connected to a rubber hose which will collect the liquid from the brine solution side into a graduated glass cylinder to measure the permeate flux. Figure 1 shows a simple sketch of the apparatus used.

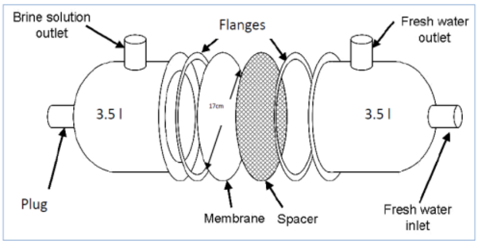

Fig .1, Apparatus used in present study

Hydraulic Head Measurements. The measurements consist of the following steps: (1) Initially a brine solution was prepared by putting 35g NaCl in a 1 liter flask and completing the volume to 1 liter with fresh water. The conductivity of the solution is measured using conductivity meter, and then the solution was placed in one of the QVF vessels and with the active side of the membrane facing this solution. (2) 3.5 l of fresh water was placed in second QVF vessel with the non active side facing the fresh water. The conductivity of the fresh water was measured. (3) The value of the hydraulic head was recorded with time in one hour intervals. This operation is repeated many times using the FO and RO membranes for initial brine concentrations range of 35 to 300 g/l.

Permeate Flux Measurements. The same procedure as above was repeated but for measuring the permeate flux. This was done by collecting the overflowing volume of permeate in a measuring cylinder and recording the time for a given volume.

Results and Discussion

Hydraulic Head Developed. The hydraulic head developed when using the FO type membrane is greater than that obtained when using RO type membrane as shown in table 1 below which lists the head developed (H) per unit area of membrane after 24 h for initial brine concentration (C) from 35 to 300 g / L using RO and FO membranes.

Table 1, Head developed (H) at different initial brine concentration (C) Using RO and FO membranes after 24 h at room conditions [15].

C	H (RO)	H (FO)
35	6.24	12.90
100	13.30	17.65
165	18.06	27.69
230	26.61	34.35
300	33.12	41.54
g / L	m / m^2 . day	m / m^2 . day

The relation between the initial brine concentration (C) and the head developed (H) can be represented by the following proposed equation:

$$H=KC^N \tag{1}$$

Where K and N are constants that depend on the type of membrane used. Table 2 below, lists the values of the constants in equation 1 for RO and FO membranes.

Table 2, Constants of equation (1) for RO and FO membranes [15].

Membrane	RO	FO
K	0.3931	1.6437
N	0.7687	0.5542
R^2	0.9915	0.9511

Permeate Flux. The permeate flux (J_w) when using FO membrane is nearly double that when RO membrane was used as shown in table 3.

Table 3, permeate flux (J_w) at different initial brine concentration (C) Using RO and FO membranes after 24 h at room conditions [15].

C	J_w (RO)	J_w (FO)
35	1.12	2.44
100	5.82	7.18
165	6.79	12.00
230	7.39	13.96
300	8.30	15.61
g / L	L / m^2 . day	L / m^2 . day

Power Generated. The maximum power (P_m) obtained from the head developed using RO and FO membranes is equal to the static pressure of the head developed and is given by the following equation:

$$P_m=\rho.g.H \tag{2}$$

Where ρ is the density of brine solution and g is the gravity of acceleration. Table 4 lists the maximum possible power in Watts per unit membrane area (W/m^2)obtained using RO and FO membranes for initial brine concentration range from 35 to 300 g / L.

Table 4, Power generated (Pm) at different initial brine concentration (C) Using RO and FO membranes [15].

C	P_m (RO)	P_m (FO)
35	0.71	1.46
100	1.51	2.00
165	2.05	3.14
230	3.02	3.90
300	3.76	4.72
g / L	W / m^2	W / m^2

Conclusions

The use of osmotic processes as a source of renewable energy is very promising, however, with the obtained results alongside the available literature it remains beyond achieving yet.

Literature Cited

1- Mi B. and Elimelech M., (2010),“Organic fouling of forward osmosis membrane: fouling reversibility and cleaning without chemical reagents”, Journal of Membrane Sicence, vol.348,pp.337-345.

2- Kravath R.E. and Davis J.A., (1975), “Desalination of seawater by direct osmosis”, Desalination, vol.16, pp.151-155.

3- Cath, T.Y., Childress, A.E. and Elimelech, M. (2006), “Forward osmosis: Principles, applications, and recent developments”, Journal of Membrane Science,vol. 281,pp.70-87.

4- Cartinella J.L., Cath T.Y., Flynn M.T., Miller G.C., Hunter K.W. and Childress A.E., (2006), “Removal of natural steroid hormones from wastewater using membrane contactor process”,Environmental Scince &Technology, vol.40,pp.7381-7386.

5- Cath T.Y., Gormly S.,Beaudry E.G., Flynn M.T., Adams V.D. and Childress A.E.,(2005), "Membrane contactor process for wastewater reclamation in space.part I. Direct osmotic concentration as a pretreatment for reverse osmosis", Journal of Membrane Science,vol.257,pp.85-98.

6- Holloway R.W., Childress A.E., Dennett K.E. and Cath T.Y.,(2007), "Forward osmosis for concentration of anaerobic digester centrate", Water Research, vol.41,pp.4005-4014.

7- Tang W. and Ng H.Y.,(2008), "Concentration of brine by forward osmosis:performance and influence of membrane structure", Desalination, vol.224,pp.143-153.

8- Achilli A., Cath T.Y., Marchand E.A. and Childress A.E.,(2009), "The forward osmosis membrane bioreactor: alow fouling alternative to MBR processes", Desalination, vol.239,pp.10-21.

9- Garcia-Castello E.M., McCutcheon J.R. and Elimelech M., (2009), "Performance evaluation of sucrose concentration using forward osmosis", Journal of Membrane Science, vol.338,pp.61-66.

10- Jiao B., Cassano A. and Drioli E.,(2004), "Recent advanced on membrane processes for the concentration of fruit juices: areview",Journal of Food Engineering, vol.63,pp.303-324.

11- Yang Q., Wang K.Y. and Chung T.S., (2009), "Anovel dual-layer forward osmosis membrane for protein enrichment and concentration", Separation and Purification Technology, vol.69, pp.269-274.

12- Baker R., (2004), "Membrane Technology and Applications", 2nd ed., Wiley.

13- Loeb S., (2002) "Large-scale power production by pressure-retarded osmosis using river water and sea water passing through spiral modules", Desalination, vol.143, pp.115–122, cited in reference 24.

14- Aaberg R.J., (2003) "Osmotic power—a new and powerful renewable energy source", ReFocus,vol. 4, pp.48–50, cited in reference 24.

15- Ghazi F. Naser,(2011), " Measurement of Static Water Head Developed by Forward and Reverse Osmosis", M. Sc. Thesis, Chemical Engineering Department, of the College of Engineering, University of Baghdad.