Osmotic backwash process in RO membranes

Neta Avrahama, Carlos Dosoretzb, Raphael Semiatb*

*aCivil and Environmental Engineering Department, Grand Water Research Institute — Rabin Desalination Laboratory, Haifa, Israel
bChemical Engineering Department, Grand Water Research Institute — Rabin Desalination Laboratory, Haifa, Israel
email: cesemiat@tx.technion.ac.il

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Abstract
The backflow process in reverse osmosis membranes induced by the osmotic pressure of a salt feed solution was investigated. The work was performed on an improved RO system based on 2.5" spiral wound module. The results showed influence of the salt concentration in, translated as osmotic pressure driving force. An important phenomena observed was that the flux through the membrane tends to decrease with the increase of salt concentration, probably due to secondary concentration polarization effects in the permeate side.

1. Introduction
Membrane fouling is an unavoidable phenomenon in water and wastewater desalination. When fouling occurs on the membrane surface the permeation decreases, the trans-membrane pressure increases, the permeate quality may decrease and the membrane may be damaged.

Major fouling causes are scaling — precipitation of calcium and magnesium salts, silica, etc., organic material tends to absorb on the membrane surface and may form a substratum to biological activity.

Biofouling: bacteria may cause biofouling. This occurs when bacteria settles on top of the membrane and nutrients are available for growth; i.e., biofilm formation.

The flux in the membrane in known to follow:

\[ J_v = L_p \times [ \Delta P - CP \times \Delta \pi ] \] (1)

where \( J_v \) permeate flux; \( \Delta P \) operation work; \( CP \) concentration polarization; \( \Delta \pi \)-osmotic pressure.

The concentration polarization is given by

\[ CP = \frac{C_w - C_p}{C_b - C_p} = e^{\left(\frac{J_v}{k}\right)} \] (2)

\[ k = \frac{D}{\delta} \] (3)

where \( C_w \) is the membrane wall concentration, \( C_p \) the permeate concentration, \( C_b \) the feed concentration, \( k \) the mass transfer coefficient, \( D \) diffusion coefficient and \( \delta \) the boundary layer thickness.

*Corresponding author.
Previous work may be found in Liberman (2004) and Sagiv and Semiat (2005). The work included the parameters: feed concentration, working pressure, feed flowrate along the membrane and operational pressure difference during backwash.

2. Results and discussion

Eq. (1) represents the driving force for osmotic backwash. It depends on the term inside the brackets: a positive value will cause RO flow, while a negative value will cause backwash, i.e., direct osmosis. A negative value will take place if the absolute value of the right term, that represents the osmotic pressure at the membrane wall, will be higher than the value of the left term which represents the operating pressure drop across the membrane. The osmotic pressure may be increased by increasing the concentration of the salt in the feed side. The operating pressure reduction may be achieved either by reducing the feed pressure or by increasing the pressure at the permeate side. The later is problematic for two reasons. The membrane cannot tolerate high pressure on the permeate side, above the operating pressure of the feed side — it will collapse. The second reason is that all piping on the permeate side are designed for low pressure (e.g., atmospheric pressure) and increase the pressure on this side needs a significant changes in the design.

Other parameters may also affect the osmotic flow, as the level of CP, which is dictated by the flux through the membrane, the temperature, which is very limited, etc.

The feed concentration increases the osmotic pressure at the feed side of the membrane. By reducing the operating pressure at the feed side to zero, the driving force is related to the osmotic pressure that is changed with feed concentration. Fig. 1 represents the case where the accumulation with time of the osmotic backwash flow was measured as function of the salt concentration in the feed stream. From the figure it is obvious that the slope of the accumulated flow is reduced with time in all curves, until the flow ceased. This is due to the reduction of the concentration on the feed side. Also a negative CP is formed close to the membrane and this reduces the driving force, especially at relatively high feed concentrations.

Fig. 1 summarizes the results of a set of experiments which tested the influence of the feed concentration. A RO run was operated using a NaCl solution at different concentrations. After the system reached a steady operation, the backwash process was operated for each feed concentration, using $\Delta P = 0$ bar (operating pressure between the feed and the permeate side during the backwash period). It can be observed that the cumulative backwash volume increased with the salt concentration from 0.69 to 2.76% and then start to decrease as the salt concentration increased. The reason for this behavior is believed to be related to a concentration polarization effect on the permeate side, that increased with the concentration of the feed and caused the reduction of the backwash driving force.
3. Conclusions

- The accumulated wash volume increased with the solution concentration up to a certain level and then decreased. This is attributed to the secondary concentration polarization layer at the permeate side.
- Cumulative backwash volume slightly increased after operating at higher RO pressure.
- The cumulative backwash volume is not affected by the flow along the membrane, yet it is decreased when the flow is stopped.
- It was shown that the main influence on the backwash rate is the difference between the operational pressure and the osmotic pressure of the solution.

References