Graduate Student, Science and Engineering

Pilot Scale Osmotic Concentration Process for Reducing Wastewater Volumes from Gas Processing Facilities in Qatar

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Abstract

Over the past 15 years, there has been increasing attention in the development of forward osmosis (FO) technology as a low-energy solution to wastewater treatment. The significant energy benefit arises in applications where direct recovery of the permeate product from the draw solution (DS) is obviated such as osmotic concentration (OC) process.

In the current work, an OC pilot unit was applied for wastewater volume reduction from gas field operations in Qatar. The pilot unit uses seawater (40 g/L TDS) as a DS and wastewater generated during gas operations as a feed. This feed water is of comparatively low conductivity (~2 g/L TDS).

Two hollow fiber FO membranes (Toyobo and NTU) were tested to assess their performance and fouling propensity. Results demonstrated that the membrane can achieve feed water recoveries up to 90%. Flux ranges from 1.5 to 12 LMH for feed recoveries between 60 and 90%. Above all, the pilot unit maintained a stable water flux ranges from 1.62 to 6 LMH at 75% feed recovery for over 48 h of continuous operation.

Introduction

- FO is based on the osmosis phenomena.
- The diffusion of water through a membrane barrier from a low to a high solution concentration.

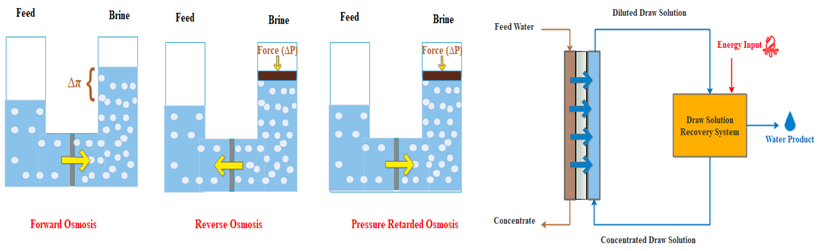

Figure 1. The Concept of the FO process.

- FO has the advantages of high solute rejection, low energy consumption, and low fouling propensity.
- However, to recover the permeated water, a further step is required (DS regeneration).

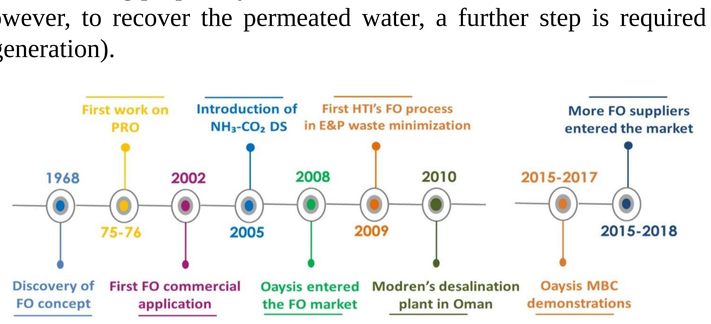

Figure 2. FO technology development timeline [1].

- FO is explored around 80 years ago as a feasible desalination process.
- Earliest commercial development was by Hydration Technology Innovations (HTI) in 2002 for emergency potable water supply for the US military.

Methodology

- An adaptation FO technology, referred to as osmotic concentration (OC).
- Feed water is of comparatively low conductivity (~2 g/L TDS)
- Readily available seawater or brine from desalination plants as the DS (40 g/L TDS).
- Instead of recovering water from draw solution, the diluted draw solution is discharged to the ocean

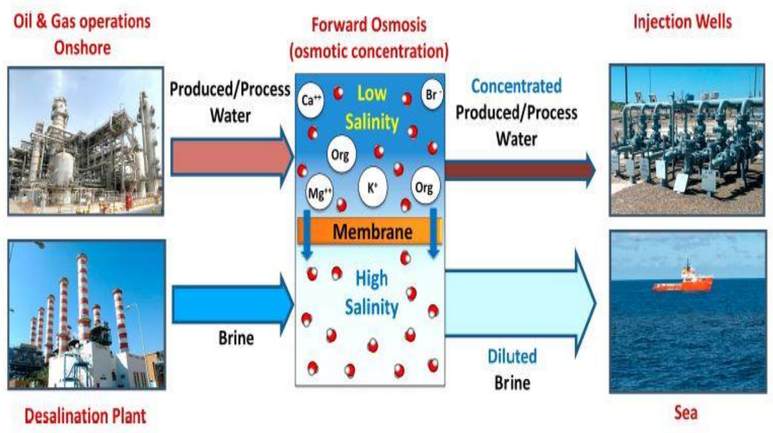

Figure 3 Osmotic concentration (OC) process for wastewater volume reduction [2].

- A proof of the concept has already been proven at bench-scale against real wastewaters.
- Reduction-by at least 50%- of the volume of PPW from gas operations at a low-energy (<0.2 kWh/m^3)

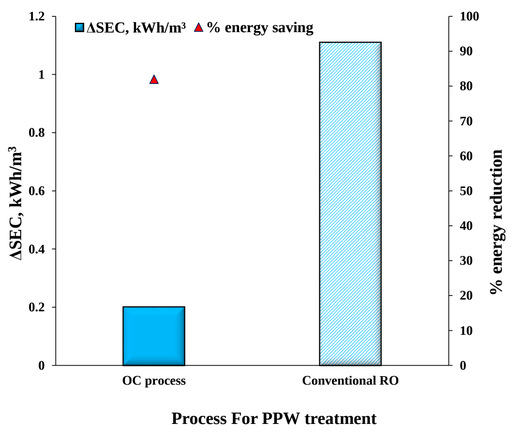

Figure 4 Energy consumption of OC process against classical RO.

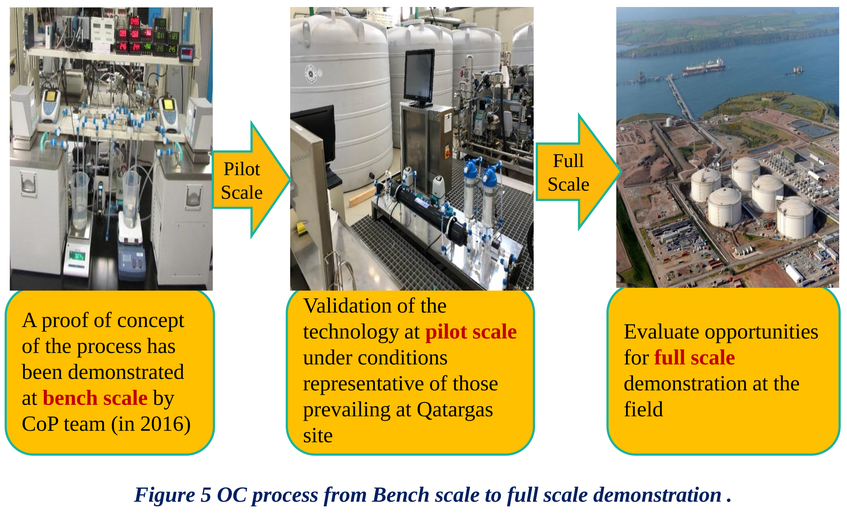

Figure 5 OC process from Bench scale to full scale demonstration .

- The system is designed based on batch operation of 5000 L PPW feed
- The pilot unit (Fig. 6) consists of four 5000 L tanks, clean-in-place tank, two diaphragm pumps, one transfer pump, filters, and hollow fiber FO membrane modules.
- Two hollow fiber FO membranes (Toyobo and NTU)
- Toyobo is operated under one-pass through, while NTU runs in a recirculation mode

Figure 6 OC pilot-scale test unit.

Results

The key outcomes of this study is be summarized as follows:

i. Tests on hollow fiber configuration of two membranes (Toyobo & NTU) demonstrated the technical viability of the OC process for wastewater volume reduction.
ii. Recovery of wastewater volumes up to 90% (Fig. 7) for both membrane products under different operating conditions.
iii. The FO pseudo steady-state fluxes (Fig. 7) achieved is ranged from < 6 to ~12 LMH for NTU, and 1.7 to 2.2 LMH for Toyobo.
iv. Tests on Toyobo and NTU membranes, revealed the latter to possess higher flux (12 vs 2 LMH) using synthetic wastewater as feed.

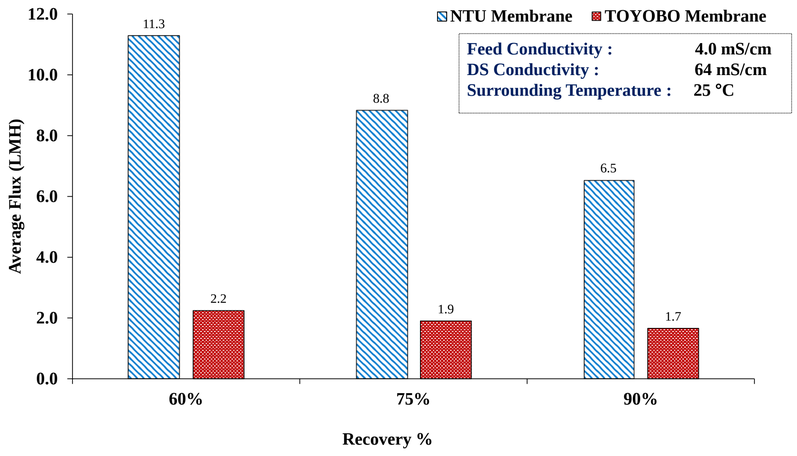

Figure 7 Toyobo and NTU membrane fluxes under different water recoveries.

v. Solute fluxes (RSF) (Fig.8) indicated the higher sensitivity of Toyobo membrane for NaCl, 65 cf. 38 mmol/m^2.h for NTU.
vi. Organic/inorganic solute rejection tests revealed almost double rejection performance for NTU as compared Toyobo. However, both membranes possess significant high rejections (**99%**)

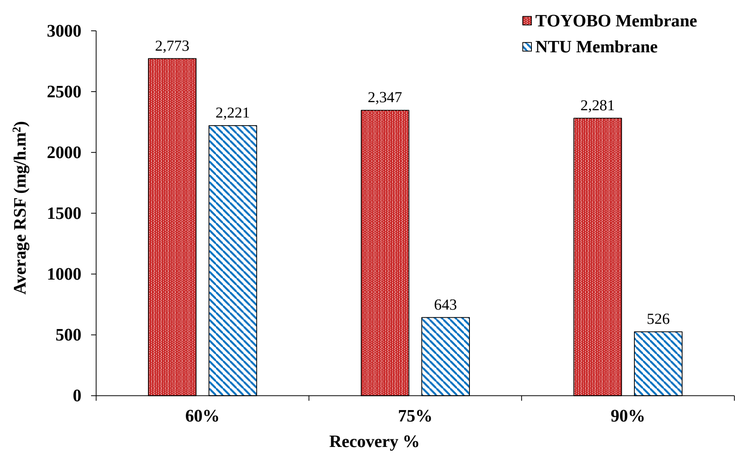

Figure 8 Toyobo and NTU RSF under different water recoveries.

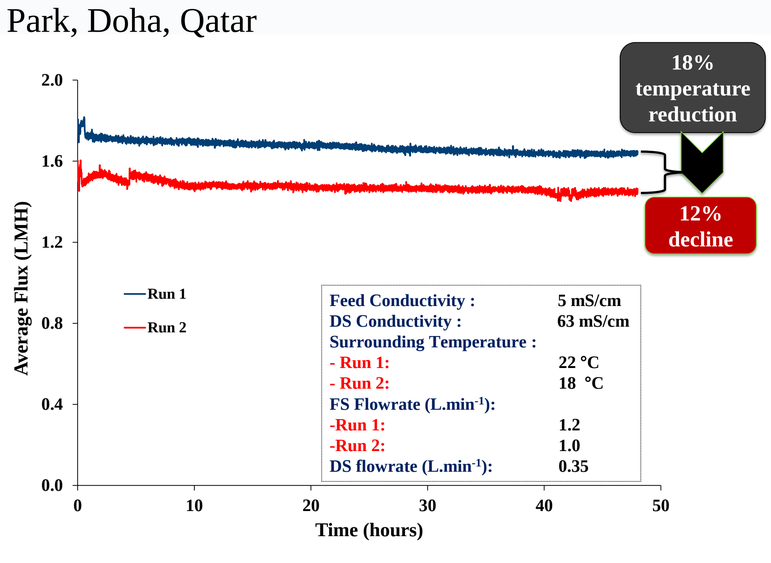

Figure 9 Long-term evaluation of Toyobo membrane under average 1.1 L.min^{-1} feed flowrate and 0.35 l.min^{-1}DS flowrate. Feed was concentrated by 75%

vii. Testing the pilot unit under extended period of operation (Fig. 9 & Fig 10) clearly revealed the stable flux trend for both Toyobo and NTU membranes at 75 % feed recovery using seawater and synthetic wastewater feed.
viii. Similar results were obtained from duplicated experiments.
ix. However, there are differences in the flux values obtained in summer and winter which is attributed mainly to the effect of the temperature.

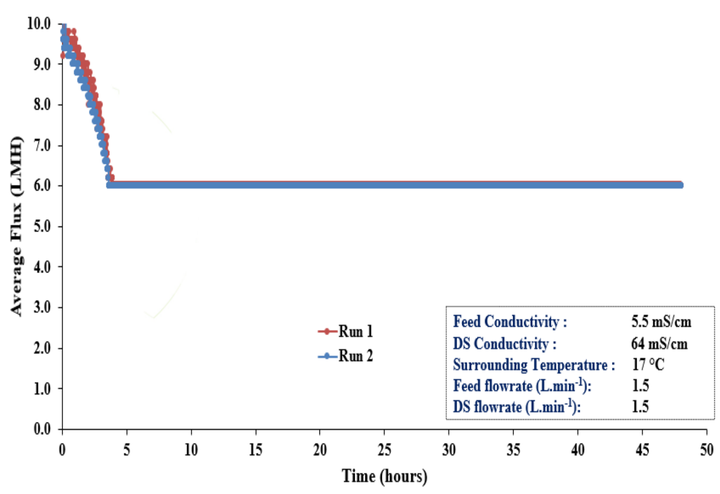

Figure 10 Long-term evaluation of NTU membrane under 1.5 L.min^{-1} feed flowrate and 1.5 L.min^{-1} DS flowrate . Feed was concentrated by 75%

Conclusions

- Although the application of FO for desalination has been demonstrated since the mid-1970s, it is only in the last decade its use for large scale applications has been considered potentially viable. The significant energy benefit arises only in applications where direct recovery of the permeate product from the draw solution (DS) is obviated such as osmotic concentration (OC) process.
- The current study demonstrated the technical viability of osmotic concentration process for reducing wastewater disposal injection volumes from Qatari gas fields with synergetic effect of minimizing brine discharged to the Gulf from desalination plants.
- The OC process revealed considerably low energy consumption for wastewater disposal volumes reduction. The pilot plant was successful in reducing the wastewater volume by 90%.
- Two hollow fiber membranes demonstrated stable high water flux (up to 12 LMH) with minimal reverse solute fluxes. Moreover, both membrane products (Toyobo and NTU) showed high organic and inorganic rejection (99 %).

Acknowledgements

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