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Production of Membrane Treated Saline Water After Plant Operation from The Rest State

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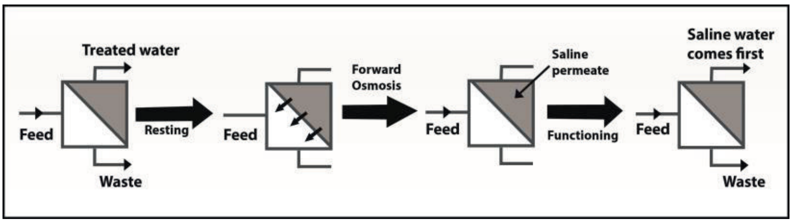
Abstract: Desalination is achieved by pressure-driven membranes, e.g., reverse osmosis (RO) and nanofiltration (NF) water treatment methods. To combat salinity issues state and private organizations introduced RO and NF treatment plants with limited success mostly due to their inappropriate use and the plants are operated for specific periods to conserve energy. Upon restoring plant operation from the idle state, we noted spiked TDS levels in the permeates for about 15 minutes. We used a laboratory-scale RO/NF membrane treatment plant in batch mode for experiments. Three water systems were used as raw water and examined the solutes flux mechanisms to resolve the observed enhanced TDS. During the rest state, porous substrates sandwiched between membrane active layers are filled with raw water; the permeates are filled between the interstices of the membranes. The whole system is soaked with the concentrate throughout the rest period. Due to the solute gradient, the permeate water molecules pass the semipermeable membrane into raw water and concentrate compartments. This process results in enhanced TDS levels in the permeate due to the forward osmosis (FO) process. When the treatment plant restarts, the treated water within the first 3-5 minutes results in high TDS that is not suitable for drinking.

Keywords: Reverse osmosis; Nanofiltration; Forward osmosis; TDS spike

Graphical abstract:



1. Introduction

Over 2.7 billion people worldwide, particularly in tropical countries, are affected by acute water scarcity due to excess water salinity. Most of the regions in the Dry Zone (Sri Lanka) experience acute water stress due to high salinity resulting from the intense weathering of silicate rocks. Pressure-driven membranes, e.g., reverse osmosis (RO) and nanofiltration (NF) are efficiently used throughout the world for water desalination. However, in Sri Lanka, RO-based technologies show limited success due to inappropriate use which often results from over-treated water with minimal TDS introducing palatability problems

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due to lack of solutes. Optimization of parameters of the membranes and feed water composition is important to generate treated water with desired quality. In remote villages of Sri Lanka, membrane treatment plants are operated for a specific time period, and the treated water is stored in a tank for distribution. We have noted a sudden increase in the TDS levels of the treated water for 8-15 minutes at the membrane treatment plant in Netiyagama primary school (8°19'53.4"N 80°36'04.8"E). Water type, improper maintenance, evaporation of treated water, and membrane fouling are the main concerning reasons for the above problem. (Wu et al., 2022)

Commercially available RO and NF membranes are consisting of two or three layers. RO membranes are mainly layered as a polyester support web, a microporous polysulfone interlayer, and an ultra-thin polyamide barrier layer. (Filmtec - Lenntech, n.d.)

These RO and NF membranes are prepared for treat water in pressure driven process but without pressure input or idle periods they act as semipermeable membranes which leads to water permeation according to two different osmotic pressures. (Johnson et al., 2021) This research was done to examine the solutes flux mechanisms to resolve the observed enhanced TDS.

2. Methodology

Laboratory scale RO (FILMTEC TW30-1812-75, 12 Lph at 0.34 MPa) and NF (KoonSon NF-1812, 15.83 Lph at 0.48 MPa) membrane combination was used for the batch mode experimental setup.

Ultra-filtered distilled water (pH- 5.37, TDS=00 ppm), Kandy Water Supply (pH- 6.37, TDS=40 ppm) and Netiyagama village water (pH- 7.34, TDS=150 ppm) were used as feed water. Three experimental modes were used; a. RO only, b. NF only c. RO and NF only. The feed water pressure and the treated water TDS levels were monitored in situ. On each occasion, the treated water TDS has monitored a function of system downtime and feed water pressure over a period of 20 minutes. TDS measurements were taken from a portable pH/EC/TDS meter.

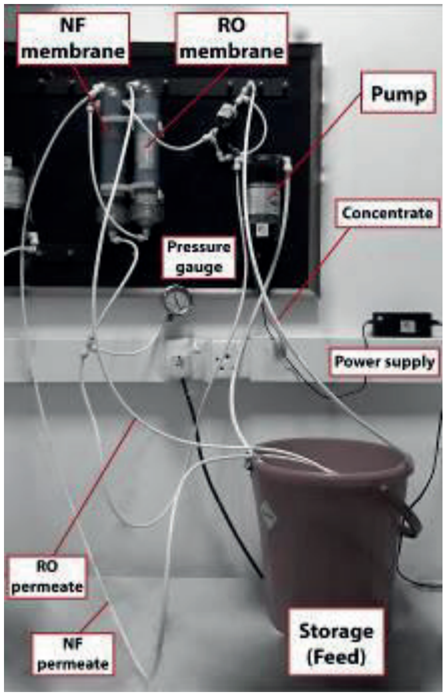

Figure No.01: Experimental setup

3. Results and discussion

During the idle time, most of the membranes retained feed water and it soaked in concentrate forming TDS gradient. We have noted a sudden increase in the TDS levels of the treated water for 4-10 minutes depending on the pressure input or the flow rate. Higher flux occurred in high pressure and it is taking less time to give a steady TDS level.

Water samples were filtered through ultrafiltration to remove bulky molecules which can be causing membrane fouling. The setup was run with tap water until the four measurements (feed, RO treated, NF treated, and wastewater) become constant levels. Water was circulated for 20 minutes and run the setup for 20 minutes after a sudden restart. Finally, it shut down for 45 minutes and restarted. The results are presented in Figures 2 and 3.

Results show that RO/NF permeates have constant TDS level water output after an immediate restart. RO/NF permeates' TDS levels depending on the TDS of feed. RO permeates TDS readings of distilled water, Kandy tap water, and

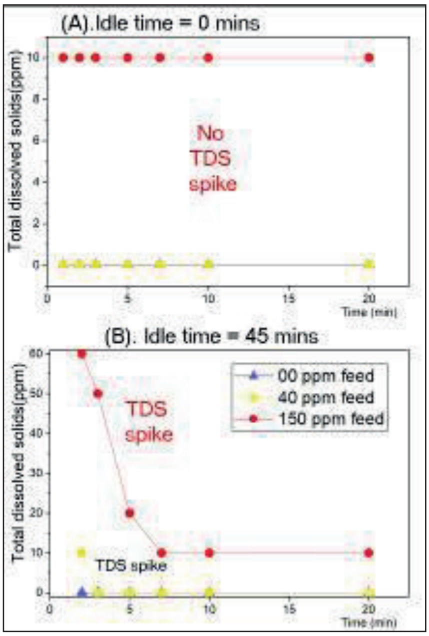

Figure No.02: Variation of TDS levels of RO permeates (A). Idle time 0 mins and (B).Idle time 45 mins

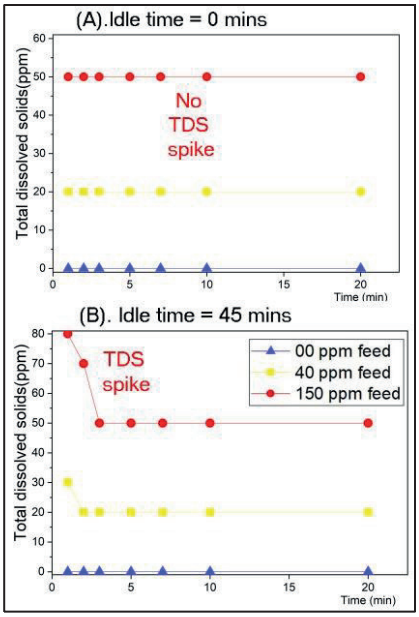

Figure No.03: Variation of TDS levels of NF permeates (A). Idle time 0 mins and (B). Idle time 45 mins

Netiyagama were 00 ppm, 00 ppm, and 10 ppm respectively, and NF permeates TDS readings were 00 ppm, 20 ppm, and 50 ppm respectively.

The RO membrane has higher salt rejection but lower flux and the NF membrane has a lower salt rejection than the RO membrane but has a higher flux. Higher TDS levels in RO and NF initial permeate outputs have recorded in tap water and Netiyagama water samples after 45 minutes of the shutdown period.

Distilled water didn't show TDS peaks in both RO and NF permeates. The degree of the TDS peak is greater with the steady TDS value of permeates. NF permeate TDS peaks have higher intensity but it spent less time to steady the TDS value because NF membranes have higher flux. RO permeate TDS peaks show a higher difference and the time taken to steady TDS level is higher compared to the NF membrane as the flux is lower in the RO membrane.

The RO/NF permeates of distilled water remained constant at 00 ppm and in the waste stream and feed at 00 ppm. Results confirmed that there was no precipitation on the membrane or dissolving precipitates. And laboratory temperature (25°C) does not cause a change in TDS levels by evaporation in 45 minutes in considerable levels.

Figure no.04 illustrates the spiral-wound membrane structure in the commercial membrane. Reduction of permeate water volume in permeate tube was observed in both RO and NF membrane permeate tube and formation of higher TDS water was observed as below.

Table no.01 shows the reduction of volume and TDS levels in three water samples after 45 mins and 12 hours of idle times. Kandy tap water and Netiyagama water samples' permeates showed a reduction in water volume in permeate tube and forming saline water, and after 12 hours there was no measurable volume in permeate tube in both RO and NF. Distilled water sample permeate didn't show volume reduction of TDS increment even after 12 hours shutdown period. The volume reduction happened due to the osmosis process. Water molecules in low salinity water in permeate cavity permeate to the feed stream and it reduced the permeate volume and increases TDS levels. Results are proving the forward osmosis process.(Lachish, 2007; Shon et al., 2015)

Permeate/treated water is retained in the permeate carrier material and the permeate tube. The hypothesis for the initial higher salinity water permeates is to be a forward osmosis process. The formation of salinity water in permeate tube was observed in tap water and Netiyagama water samples and water permeates back to the feed stream until the osmotic pressure become equal on both sides (Feed water in feed spacer and treated water in permeate carrier material).

Figure no.05 illustrates the RO and NF processes, and formation of the TDS spikes in the permeate in fresh start of RO/NF membrane water treatment plants after shutdown period. The water trapped in permeate carrier material cannot be removed from the system, therefore removing the treated water in the permeate tube cannot avoid this problem. Formed salinity water in the permeate carrier material will flow first out from the cell when restarting the system, contaminate with newly separated fresh water and form TDS spike. The time to reach a steady TDS level of the permeate depends on the formed saline water TDS and volume, working pressure, and feed water TDS. This membrane-treated saline water that is an initial output of the desalination water plants has higher salinity little-less than the feed water.

3. Conclusions

The sudden increase of TDS levels after an idle period in the desalination plant has a reason for the formation of higher TDS water in the permeate cavity due to forward osmosis process and contamination of saline water to the treated water from the fresh start. Manufacturers of the RO/NF membranes recommended feed quality water when the system is shutting down or resting. Feeding treated water or rain water when resting on the system can avoid this problem. Future work will be conduct on forward osmosis rate and membrane characterization. The TDS flux flow mechanisms will be modelled according to Fick's hydraulics

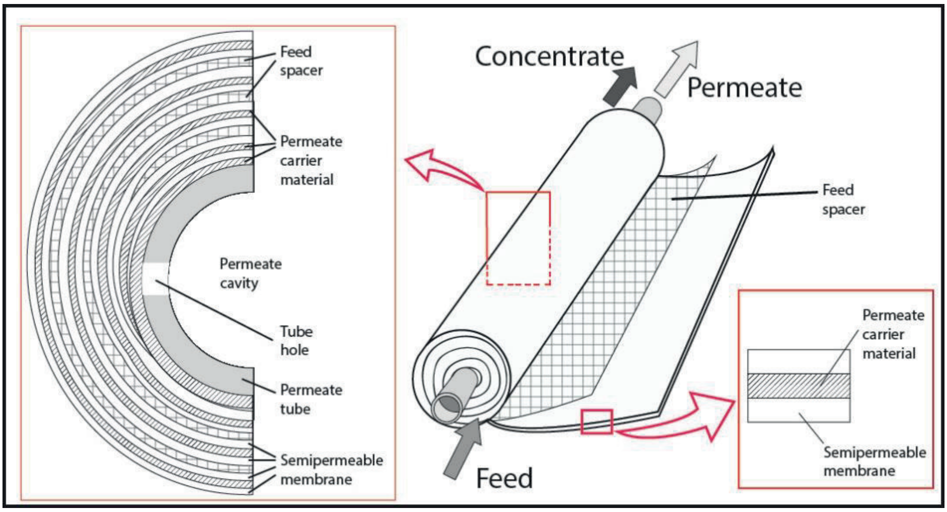

Figure No.04: Spiral-wound RO and NF Membrane module and structure

Table 1: Reduction of permeate water volume and TDS in permeate tube

Water sample	After 45 mins				After 12 hours			
	RO		NF		RO		NF	
	Water volume reduction	TDS/ppm	Water volume	TDS/ppm	Water volume reduction	TDS/ppm	Water volume reduction	TDS/ppm
1. Distilled water	no	00	no	00	no	00	no	00
2. Kandy tap water	yes	10	yes	40	yes	-	yes	-
3. Netiyagama water sample	yes	70	yes	90	yes	-	yes	-

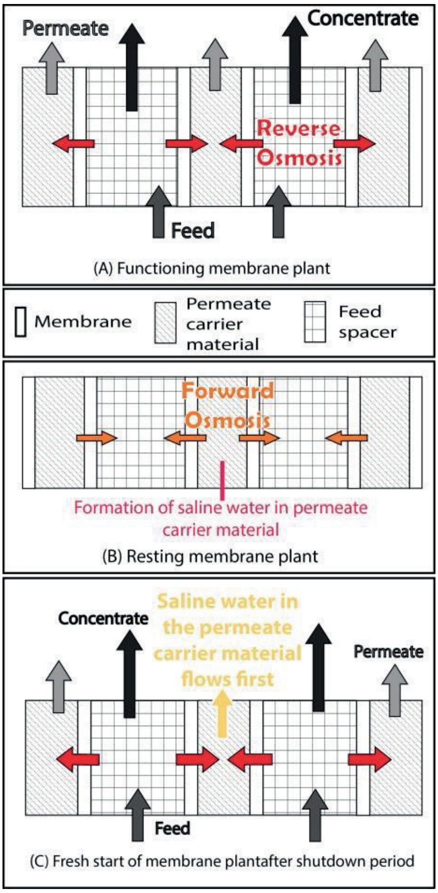

Figure No.05: Reverse osmosis and forward osmosis process in membrane process (A). Functioning (B). Resting (C). Fresh start after shutdown period

Acknowledgement

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