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Appraising Influences of Temperature and Concentration on High Rejection Nanofiltration and Their Application in Saline Water

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ABSTRACT

In view of the typical results obtained from pilot plan unit, a trial on the nanofiltration (NF) demonstration unit is not only logical but also essential to determine the conditions of the operations such as feed pressure and permeate TDS. A significant progress is made in understanding the effect of the feed temperature on the nanofiltration performance by using different concentrations of saline water that cover both high salinity brackish water and the seawater range 10K ppm, 20K ppm, 30K ppm and 40K ppm. A complete demonstration unit is constructed in this research applying a NF spiral wound membrane manufactured by Filmtec company type NF90-2540 that shows a high salt rejection. The simulation' runs by the latest simulation software; WAVE by Filmtec company were compared with the experimental results. The permeability percentage of the nano polymer for both monovalent ions such as sodium and chloride ions and the divalent ions such as calcium, magnesium and sulphate ions are discussed in this study as well. It was observed that feed pressure decreased with increasing feed temperature and decreasing feed TDS. Moreover, the salt rejection decreased with increasing feed temperature and feed TDS. The feed pressure results of NF90-2540 proved that the NF power consumption is lower than RO.

Keywords

Nanofiltration, permeate TDS, feed pressure, feed water temperature.

INTRODUCTION

Egypt like other countries around the world suffers from water secrecy so that using seawater desalination was not an option, but it was a mandatory. During the last 10 years, Egypt duplicated the seawater reverse osmosis (SWRO) and brackish water reverse osmosis (BWRO) plants many times. The nanofiltration is a physical process separation where water under driven in passed to a nano pore sized membrane were dissolve ions, multivalent [1,2] will be rejected. Dow water and process solutions has launched a new design software, water application value engine (WAVE), which integrates multiple technologies into one tool. The nanofiltration pre-treatment before the reverse osmosis (RO) will improve the unit performance in chemical and electrical consumption [3,5]. Acid and anti-scalant consumption will be lower compared to a unit without nanofiltration [6]. High pressure pump rating pressure will be lower due to the decrease in the total dissolved solids (TDS) of the feed [7]. Piping grade will be lower due to the decrease in TDS that will decrease the corrosion effect [8]. The use of nanofiltration membranes instead of seawater membranes is economical due to removing of divalent ions [9,10]. Many researchers have used NF membranes in desalination of well water with similar TDS and chloride concentrations to those found in Gaza Strip ground water. In the present work, temperature effect on nanofiltration is studied. Paugam et al. tested three commercial NF membranes denoted as MPS44, DESAL, and NF70 for the desalination of brackish water [11]. The study showed a high sulphate and chloride rejection by NF70 and moderate same monovalent anions rejection rates by MPS44 and DESAL membranes but at concentrations of below 500 mg/L. Luo et al. studied how salt concentration and pH effects on nanofiltration salt rejection and flux and reported that the permeability increased as a result of high pH and salt concentration [12]. This is due to effective membrane pore size can increased by high pH. Moreover, the multi-mechanisms like electronic effect, membrane swelling and charge variation explain the effect of pH on the membrane performance. The NF membrane (NE4040-90) ability to reject ions from low water salinity at operating pressures from 4 bar to 10 bar has been discussed by Izadpanah et al [13]. In the previous study, three samples of low water salinity were tested with total dissolved solids 4970, 7220, 9750 ppm. The Ca^{2+} ions, Mg^{2+} ions and total hardness rejection is 96-98%, whereas the rejection of total dissolved solids was 79-89%. But at higher pressures, the rejection decreased slightly. Hilal et. al, studied NF membranes and reported removal of turbidity, microorganisms, hardness, and fraction of TDS [14].

The effect of ion composition on NF rejection was studied [15,16]. As the salt concentration increases, the rejection of anions increases, while the rejection of cations decrease. Al-Hajouri et al. studied the performance of NF membranes during SWRO pre-treatment with regard to conductivity and feed pressure over eight years. The feed pressure varies between 18 and 38 bar. The initial permeability is high. However, a decrease in NF salt rejection was discovered due to fouling. Chemical cleaning was conducted each 9 months [17].

Walha et. al, reported that the temperature affected the membrane properties [18]. It was reported that temperature had an effect by varying the diffusion of water and ions [19,20]. Sharma and Chellam discussed that at high temperatures, the polymer chain within the separation layer will increase and becomes more effective, to exaggerated membrane pore sizes [21]. Researchers reported that rejection increased slightly and for Na^+ and Cl^- ions decrease slightly [22,23]. Moreover, the temperature has an impact on scale formation on NF membrane surfaces. For specific precipitates, the thermodynamic solubility product could be temperature dependent [24]. Researchers terminated that carbonate particles of calcium were detected on the NF membrane surface at 20°C. With the rise in temperature, the solubility product constants of calcium carbonate and calcium sulphate decreases, producing a homogenous crystallization. Within the bulk concentration, carbonate precipitation of calcium happens on the membrane surface [25-27].

2. EXPERIMENTAL

There are two types of nanofiltration membranes manufactured by DUPONT filmtec, NF90 and NF270. Both membranes consist of 3 layers, polyester layer, polysulfone layer and polyamide which is the active layer. NF90 has 17.1% porosity while NF270 has 11.7% porosity. NF90 provides 85-95% $CaCl_2$ salt rejection and greater than 97% $MgSO_4$ salt rejection but with lower permeate flow than NF270. NF270 provides 40-60% $CaCl_2$ salt rejection and greater than 97% $MgSO_4$ salt rejection but with higher permeate flow than NF90 [28].

2.1. NF Demonstration unit (Plant description)

The NF demonstration unit is presented in Figure 1 and consisted of the following equipment:

Raw water tank; polyethylene tank with volume 500 L, feed water pump; horizontal centrifugal pump from china (LEO brand) with flow capacity of 10-45 L/min and head of 25-43 m, multimedia filter; consisting of manual control valve of in-out 1.0 inch port and filter pressure vessel with diameter of 10 inch and height of 54 inch with thread opening of 2.5 inch both of (canature brand) from china. The vessel is filled with 50 kg of gravel, 50 kg of sand and 25 kg of anthracite, cartridge filter; polyethylene housing of size 4-inch diameter and 20-inch length filled with polypropylene cartridge 20 inch of length and 5-micron pore size (Microtex brand), high pressure pump; piston pump fuel injection (MATSU-SAKA) from china with flow capacity of 40-52 L/min and head of 410 m, stainless steel 304 skids holding the membrane pressure vessel, membrane and high-pressure pump along with the instruments and cartridge housing, membrane pressure vessel; fiber-glass 2.5-inch diameter housing with 40 inch in length (codeline brand), nanofiltration membrane; 2.5-inch diameter membrane with 40 inch in length, there were two types of membranes used in this experiment; DUPONT Filmtec NF90-2540 with permeate flow rate of 2.6 m^3/d with salt rejection 97% and DUPONT Filmtec NF270-2540 with permeate flow rate of 3.2 m^3/d with salt rejection higher than 97%, and permeate tank; polyethylene tank with volume 500 L.

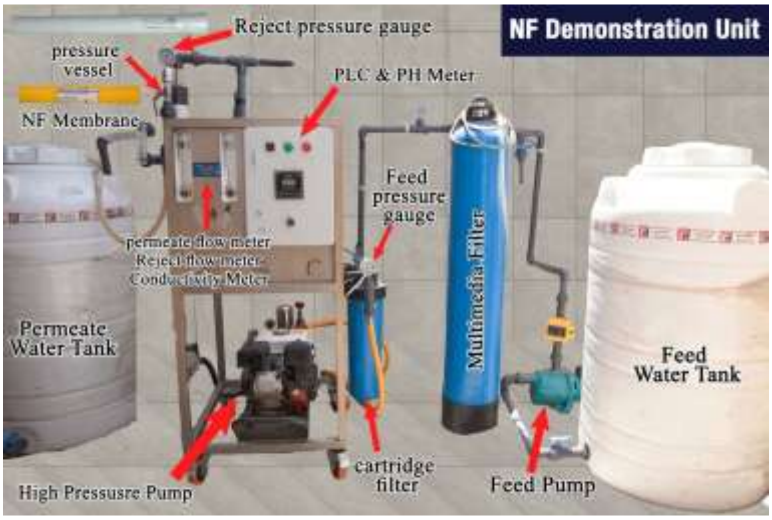

Figure 1. NF demonstration unit.

2.2. Chemical composition of NF feed (Solution preparation)

By applying plant analysis, four different concentrations of saline water prepared as a simulation of the different salinity types of seawater. The first solution was 10008 ppm of total dissolved solids containing 7406 mg/L of monovalent ions will be represented as NaCl, and 2602 mg/L of divalent ions will be represented as $MgSO_4$. Prepared by dissolving 7.4 gm of NaCl in 1.0 L of distilled water in a 500 L tank and 2.6 gm of $MgSO_4$ in 1.0 L of distilled water in a 500 L tank. The second solution was 20023 ppm of total dissolved solids containing 16619 mg/L of monovalent ions will be represented as NaCl, and 3404 mg/L of divalent ions will be represented as $MgSO_4$. Prepared by dissolving 16.6 gm of NaCl in 1.0 L of distilled water in a 500 L tank and 3.4 gm of $MgSO_4$ in 1.0 L of distilled water in a 500 L tank. The third solution was 30048 ppm of total dissolved solids containing 25541 mg/L of monovalent ions will be represented as NaCl, and 4507 mg/L of divalent ions will be represented as $MgSO_4$. Prepared by dissolving 25.5 gm of NaCl in 1.0 L of distilled water in a 500 L tank and 4.5 gm of $MgSO_4$ in 1.0 L of distilled water in a 500 L tank. The fourth solution was 40066 ppm of total dissolved solids containing 34457 mg/L of monovalent ions will be represented as NaCl, and 5609 mg/L of divalent ions will be represented as $MgSO_4$. Prepared by dissolving 34.5 gm of NaCl in 1.0 L of distilled water in a 500 L tank and 5.6 gm of $MgSO_4$ in 1.0 L of distilled water in a 500 L tank.

2.3. Operation of NF demonstration unit (Process description)

the plant is automatically operated, first the saline solution is prepared in 500 L polyethylene tank, the conductivity is measured by portable TDS meter achieving the desired TDS and the heater used to change the temperature of the solution as required.

The prepared solution pumped by the feed pressure pump with flow rate 0.71 m^3/h at pressure 4 bar. Both pressure and flow rate were measured by pressure gauge and flow meter sequentially. A multimedia filter is used to filtrate the feed water from contaminated impurities and colloidal solids. A three-cycle control valve is installed on the top of the vessel in order to control the water flow in the multimedia filter. Sediment filter with 20 inches length and 5-micron pore size is used before the feed water entrance to the membrane. A high-pressure pump is used to increase the water pressure to reach the required pressure at the entrance of the NF membrane, two flow meters are used to measure both the permeate flow and the reject flow.

2.4 NF Simulations by WAVE software (Membrane type NF90-2540)

In this part of the WAVE software simulation procedure, the membrane type NF90-2540 functions as a nanofiltration membrane. The filmtec™ NF90 membrane elements provide high productivity performance while removing a high percentage of salts, nitrate, iron and organic compounds such as pesticides, herbicides and THM precursors. The low net driving pressure of the NF90 membrane allows the removal of these compounds at low operating pressures.

In the four WAVE simulation group of cases starting with case 1 to case 7, the feed salinity is kept constant at 40000 ppm. In the second group of cases from 8 to 14, the feed salinity water is kept constant at 30000 ppm. While in the third group of cases from case 15 to case 22, the feed salinity is kept constant at 20000 ppm. In the last group of cases starts with case 23 to case 29, the feed salinity is kept constant at 10000 ppm. The feed flow is constant at 0.71 m^3/h because we need to keep the recovery constant at 14% to keep the permeate flow constant as well at 0.1 m^3/h. The seven-wave simulated runs for each group of cases started with the feed temperatures at 18^oC and increase the feed temperature gradually by 2^oC until reaching 30^oC. Both the feed pressure and the permeate TDS value will be reviewed in the WAVE simulation summary report and record all the data (Tables 1, 2, 3 and 4).

2.5 Experimental cases of membrane type NF90-2540

The four experimental groups of cases are recorded after preparing the solution with salinity around 40066 ppm, then 30408 ppm, 20023 ppm and 10008 ppm with note a slight change in the prepared solution with increase the solution temperature before starts each individual experiment.

According to the WAVE simulation cases from case 1 to case 7, it was noted that the feed pressure exceeds the maximum limit so that we changed the concept of this study experiments in this first experimental group only by keep the feed flow and the feed pressure constant during the experiment and record the effect of change the feed temperature on the nanofiltration system recovery, permeate flow and the permeate salinity.

The WAVE simulation cases from case 8 to case 29, we noted that there are no design warnings reviewed in the WAVE simulation summary report so that we keep the concept of this study experiments in this second experimental group by keep the feed flow, the nanofiltration system recovery and the permeate flow constant during the experiment and record the effect of change the feed temperature on the feed pressure and the permeate salinity.

Seven experimental runs for each salinity group started with the feed temperatures at 18^oC and increase the feed temperature by 2^oC until reaching 30^oC. The permeate flow, the nanofiltration system recovery and the permeate TDS value will be recorded in Tables 5, 6, 7 and 8.

3. RESULTS AND DISCUSSION

Due to the differences in water temperature throughout the year, the relationship between feed temperature, feed pressure and the permeate TDS should be taken into consideration during the design of the NF as well as RO units to have constant rates of the permeate TDS.

3.1 WAVE cases at 40000 ppm

It is detected that at the feed temperature 18^{o}C and the feed salinity 40000 ppm, the feed pressure decreased from 50.4 bar at 18^{o}C to 47 bar at 30^{o}C at constant feed flow at 0.71 m^{3}/h that exceeds the maximum feed pressure for the nanofiltration membrane type NF90-2540 (Table 1). While the maximum operating pressure of the nanofiltration membrane type NF90-2540 according to the product data sheet by the manufacturer company DUPONT is 600 psi (41 bar) so that we directly reviewed a design warning in the WAVE simulation summary report. The design warning is the feed pressure exceeds the maximum limit 41.4 bar. At permeate flow 0.1 m^{3}/h and constant system recovery at 14%, the permeate TDS increase from 1554 ppm at 18^{o}C to 3080 ppm at 30^{o}C.

Table 1. 40000 ppm TDS WAVE results utilizing NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^{o}C	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	50.4	40000	18	14	0.1	1554
٠.٧١	٤٩.٨	40000	20	14	0.1	١٧٥٢
٠.٧١	٤٩.٣	40000	22	14	0.1	١٩٧٠
٠.٧١	٤٨.٨	40000	24	14	0.1	٢٢١١
٠.٧١	٤٨.٢	40000	26	14	0.1	٢٤٧٥
٠.٧١	٤٧.٥	40000	28	14	0.1	٢٧٦٤
٠.٧١	٤٧	40000	30	14	0.1	٣٠٨٠

3.2 WAVE cases at 30000 ppm

From Table 2, it is observed that at the feed temperature 18^{o}C and the feed salinity 30000 ppm, the feed pressure is decreased from 38 bar to 35 bar at constant feed flow at 0.71 m^{3}/h. There are no design warnings reviewed in the WAVE simulation summary report. At permeate flow 0.1 m^{3}/h and constant system recovery at 14%, the permeate TDS increased from 1164 ppm to 2308 ppm.

Table 2. 30000 ppm TDS WAVE results applying NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^{o}C	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	38	30000	18	14	0.1	1164
0.71	37.5	30000	20	14	0.1	1313
0.71	37	30000	22	14	0.1	1476
0.71	36.5	30000	24	14	0.1	1656
0.71	36	30000	26	14	0.1	1854
0.71	35.5	30000	28	14	0.1	2071
0.71	35	30000	30	14	0.1	2308

3.3 WAVE cases at 20000 ppm

From Table 3, it is detected that at the feed temperature 18^{o}C and the feed salinity 20000 ppm, the feed pressure decreased from 26.5 bar to 23.9 bar at constant feed flow at 0.71 m^{3}/h. There are no design warnings reviewed in the WAVE simulation summary report. At permeate flow 0.1 m^{3}/h and constant system recovery at 14%, the permeate TDS increased from 775.7 ppm to 1380 ppm.

Table 3. 20000 ppm TDS WAVE results utilizing NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^oC	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	26.5	20000	18	14	0.1	775.7
0.71	26	20000	20	14	0.1	874.3
0.71	25.6	20000	22	14	0.1	983.3
0.71	25.1	20000	24	14	0.1	1103
0.71	24.7	20000	26	14	0.1	1235
0.71	24.3	20000	28	14	0.1	1380
0.71	23.9	20000	30	14	0.1	1537

3.4 WAVE cases at 10000 ppm

It is observed that at the feed temperature 18^{o}C and the feed salinity 10000 ppm, the feed pressure decreased 15.6 bar to 13.3 bar at constant feed flow at 0.71 m^3/h (Table 4). There are no design warnings reviewed in the WAVE simulation summary report. At permeate flow 0.1 m^3/h and constant system recovery at 14%, the permeate TDS increased from 387.6 ppm to 768.1 ppm.

Table 4. 10000 ppm TDS wave results applying NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^oC	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	15.6	10000	18	14	0.1	387.6
0.71	15.1	10000	20	14	0.1	436.8
0.71	14.7	10000	22	14	0.1	491.2
0.71	14.3	10000	24	14	0.1	551.2
0.71	14	10000	26	14	0.1	617.1
0.71	13.6	10000	28	14	0.1	689.3
0.71	13.3	10000	30	14	0.1	768.1

3.5 NF90-2540 experimental results at 40000 ppm

At the feed temperature 18^{o}C, the feed salinity 40066 ppm and feed pressure 41 bar, the nanofiltration system recovery is 8.24 %, the permeate flow is 0.06 m^3/h and permeate TDS is 2280 ppm. However, the calculated salt rejection is 94.31 % which is lower than the minimum salt rejection of the nanofiltration membrane NF90-2540 (97%). A slight change in the feed TDS is observed with raising of the feed temperature to be 40072 ppm up to 40075 ppm. The permeate TDS increase from 2280 ppm to 3933 ppm and the feed pressure keep stable at 41 bar with the increase of the feed temperature from 18^{o}C to 30^{o}C against increase in the system recovery (Table 5 and Figure 2). This could be due to the feed temperature which is directly influenced the nano polymer membrane permeability by changing the water and ions diffusion and the polymer separation layer [20-22]. At high temperatures, the chain of the nano polymer in the separation layer is increased and develop to be more active, leading to an increased pore sizes of membrane [23].

Table 5. 40000 PPM TDS experimental results utilizing NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^oC	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	41	40066	18	8.24	0.06	2280

0.71	41	40075	20	8.49	0.06	2509
0.71	41	40073	22	8.73	0.06	2757
0.71	41	40072	24	8.99	0.06	3024
0.71	41	40073	26	9.27	0.07	3303
0.71	41	40074	28	9.5	0.07	3617
0.71	41	40073	30	9.81	0.07	3933

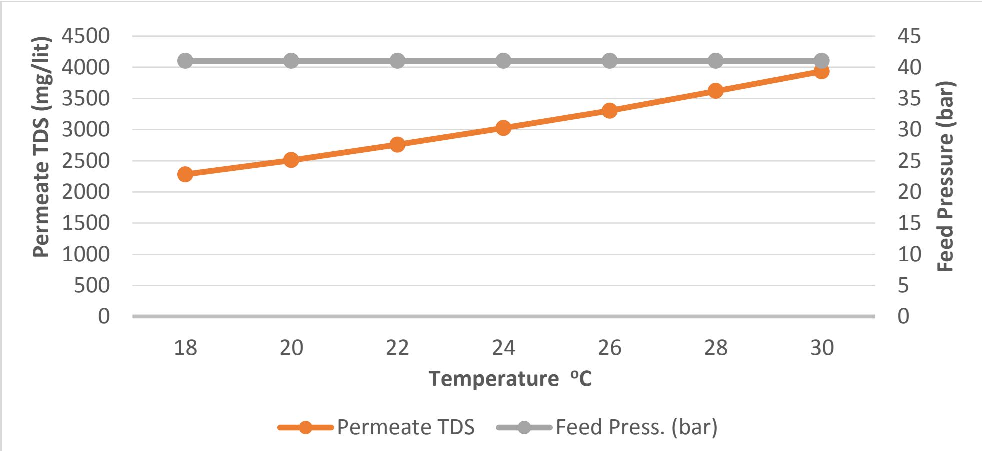

Figure 2. The effect of the feed temperature on both permeate salinity and the feed pressure at feed TDS 40K ppm by NF90-2540 at 40000 mg/L.

3.6 NF90-2540 experimental results at 30000 ppm

As shown in Table 6 and Figure 3, the permeate flow at 0.1 m^3/h and nanofiltration system recovery at 14%, the feed pressure at 39.8 bar and permeate TDS at 1171 ppm are recorded at the feed temperature 18°C. Although, the calculated salt rejection is 96.1% which is lower than the minimum salt rejection of the nanofiltration membrane NF90-2540 (97%). As the feed temperature is raised by 2°C until reach 20°C, the feed TDS increased slightly to 30054 ppm. With the increase in the feed temperature, the feed TDS is changing slightly between 30048 ppm and 30052 ppm. The permeate TDS increases from 1171 ppm to 2320 ppm and the feed pressure decreases from 39.8 bar to 36.2 bar with the increase of the feed temperature from 18°C to 30°C. This could be due to the feed temperature which is directly influenced the nano polymer membrane by changing the water and ions diffusion and the polymer separation layer [20-22]. At high temperatures, the chain of the nano polymer in the separation layer is increased and develop to more active, leading to an increased pore sizes of membrane [23].

Table 6. 30000 ppm TDS experimental results applying NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature °C	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	39.8	30048	18	14	0.1	1171
0.71	39.2	30054	20	14	0.1	1320
0.71	38.6	30052	22	14	0.1	1484

0.71	38	30050	24	14	0.1	1665
0.71	37.4	30050	26	14	0.1	1864
0.71	36.8	30050	28	14	0.1	2082
0.71	36.2	30048	30	14	0.1	2320

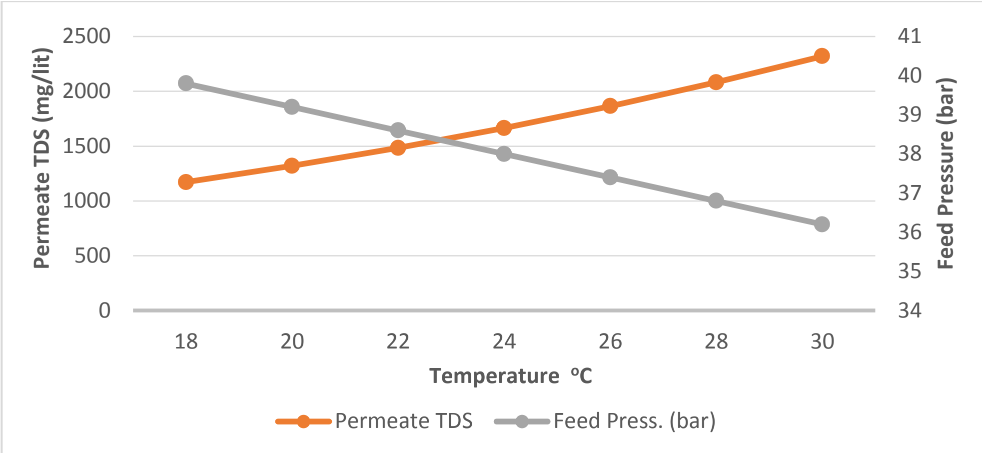

Figure 3. The effect of the feed temperature on both permeate salinity and the feed pressure at feed TDS 30K ppm by NF90-2540 at 30000 mg/L.

3.7 NF90-2540 experimental results at 20000 ppm

From Table 7 and Figure 4, permeate flow at 0.1 m^3/h and nanofiltration system recovery at 14%, the feed pressure at 28.1 bar and permeate TDS at 780 ppm are recorded at the feed temperature 18^{o}C. However, the calculated salt rejection is 96.1 % which is lower than the minimum salt rejection of the nanofiltration membrane NF90-2540 (97%). With the increase in the feed temperature to 20^{o}C, the feed TDS reached 20025 ppm. While the feed temperature increases above 20^{o}C, the feed TDS keeps changing between 20024 and 20023 ppm. the permeate TDS increase from 780 ppm to 1545 ppm and the feed pressure decreases from 24.9 bar to 28.1 bar with the increase of the feed temperature from 18^{o}C to 30^{o}C. This could be due to the feed temperature which is directly influenced the nano polymer membrane permeability by changing the water and ions diffusion and the polymer separation layer [20-22]. At high temperatures, the chain of the nano polymer in the separation layer is increased and develop to more active, leading to an increased pore sizes of membrane [23].

Table 7. 20000 ppm TDS experimental results utilizing NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature ^{o}C	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	28.1	20023	18	14	0.1	780
0.71	27.5	20025	20	14	0.1	879
0.71	26.9	20024	22	14	0.1	988

0.71	26.4	20023	24	14	0.1	1109
0.71	25.9	20024	26	14	0.1	1242
0.71	25.4	20023	28	14	0.1	1387
0.71	24.9	20023	30	14	0.1	1545

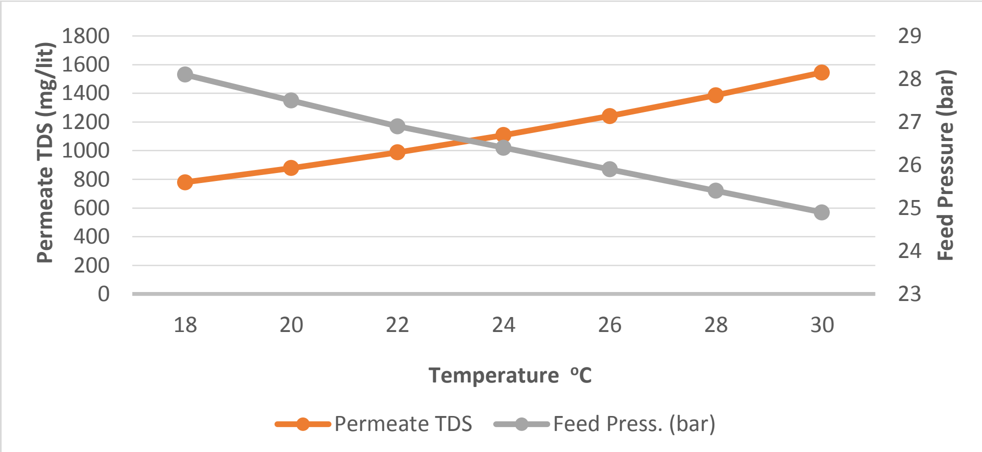

Figure 4. The effect of the feed temperature on both permeate salinity and the feed pressure at feed TDS 20K ppm by NF90-2540 at 20000 mg/L.

3.8 NF90-2540 experimental results at 10000 ppm

At the feed temperature 18°C, permeate flow 0.1 m^3/h and nanofiltration system recovery 14%, the feed pressure and permeate TDS are recorded to be 16.9 bar and 390 ppm, respectively (Table 8). Meanwhile, the calculated salt rejection is 96.1 % which is lower than the minimum salt rejection of the nanofiltration membrane NF90-2540 (97%). The feed temperature increase from 18°C to 20°C leads to a decrease in feed TDS to be 10007 ppm. However, increasing the feed temperature above 20°C, the feed TDS remains constant. The permeate TDS increase from 390 ppm to 772 ppm and the feed pressure decreases from 16.9 bar to 14.2 bar with the increase of the feed temperature from 18°C to 30°C (Figure 5). This could be due to the feed temperature which is directly influenced the nano polymer membrane permeability by changing the water and ions diffusion and the polymer separation layer [20-22]. At high temperatures, the chain of the nano polymer in the separation layer is increased and develop to more active, leading to an increased pore sizes of membrane [23].

3.9 NF90-2540 effect of feed TDS in experimental results

It is observed that permeate TDS and feed pressure increased with increasing feed TDS with respect to temperature. This could be due to the feed temperature which is directly influenced the nano polymer membrane permeability by changing the water and ions diffusion and the polymer separation layer [20-22]. At high temperatures, the chain of the nano polymer in the separation layer is increased and develop to be more active, leading to an increased pore sizes of membrane [23].

Table 8. 10000 ppm TDS experimental results applying NF90-2540.

Feed flow m^3/h	Feed pressure bar	Feed TDS ppm	Feed temperature °C	Recovery %	Permeate flow m^3/h	Permeate TDS ppm
0.71	16.9	10008	18	14	0.1	390
0.71	16.4	10007	20	14	0.1	439
0.71	15.9	10007	22	14	0.1	494
0.71	15.4	10007	24	14	0.1	554

0.71	15	10007	26	14	0.1	620
0.71	14.6	10007	28	14	0.1	693
0.71	14.2	10007	30	14	0.1	772

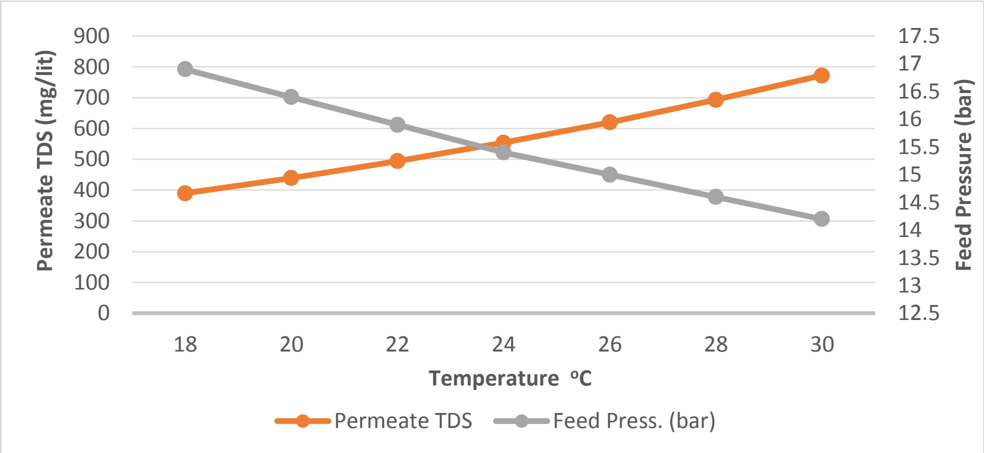

Figure 5. The effect of the feed temperature on both permeate salinity and the feed pressure at feed TDS 10K ppm by NF90-2540 at 10000 mg/L.

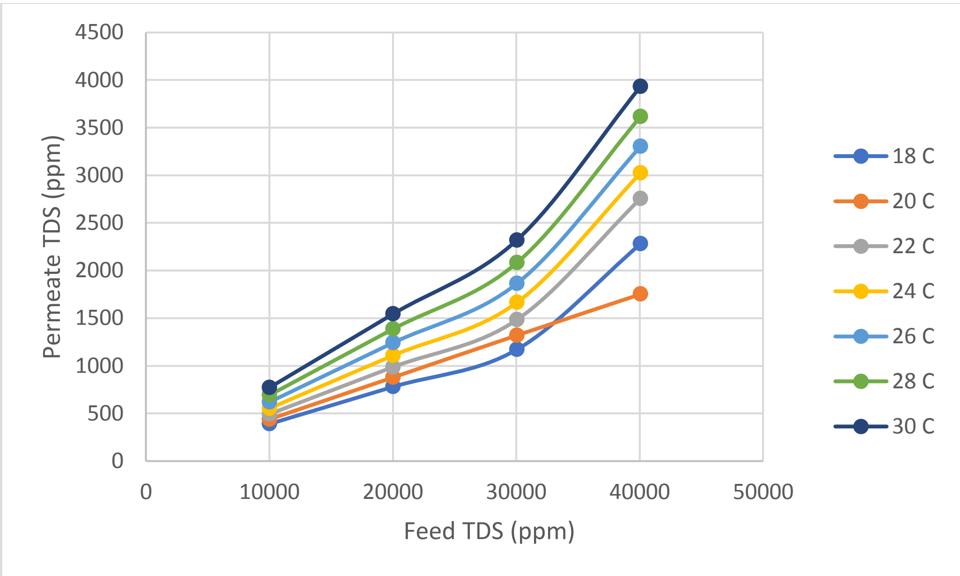

Figure 6. Effect of feed TDS on permeate TDS.

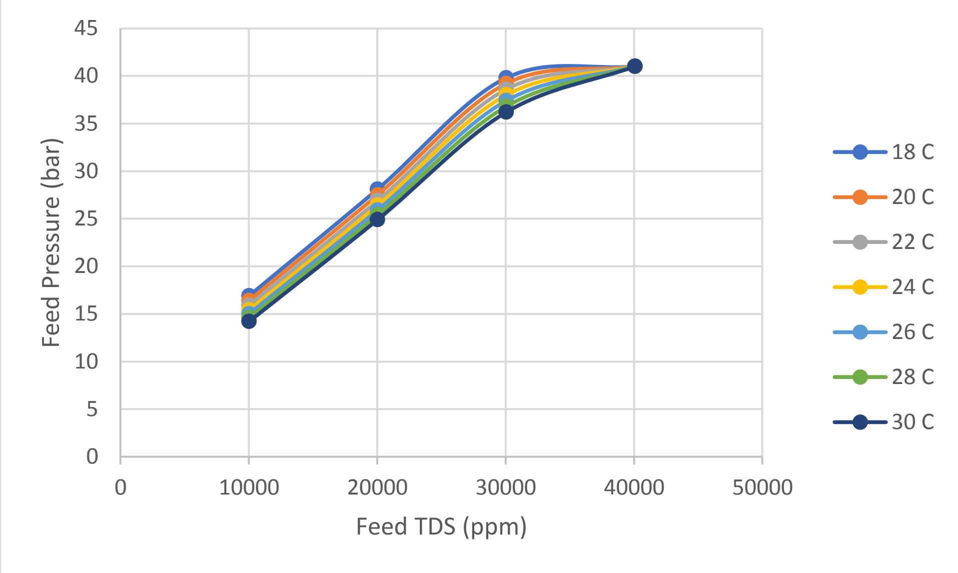

Figure 7. Effect of feed TDS on feed pressure.

4. CONCLUSION

Based on this study, applying the nanofiltration in the seawater desalination is practically successful either by the WAVE software simulation or by the corresponding recorded experimental results. Both of the simulation notes and experiential results proved that the nanofiltration could be applied with the seawater salinity in the range of 10000 ppm to 40000 ppm. The NF couldn't be applied as a stand-alone system in the seawater desalination process because permeate salinity is very high compared to the standard drinking water salinity, but it can be applied as a pre-treatment stage for RO. One of the most important outcomes from the current research is the feed temperature is directly affecting the nano polymer permeability.

Furthermore, the effect of the water temperature on the behaviour of the nanofiltration was studied. As the feed temperature increases, the salt rejection decreases and the feed pressure decreases. From the present study, it is found that the feed temperature not only influences the permeate TDS but also influences the feed pressure and the membranes salt rejection.

Moreover, utilizing the nanofiltration in the seawater desalination has an important economic feasibility because of the NF exhibited high rejection rates for divalent ions over monovalent ions and it required lower feed pressure than RO that exhibited the same rejection rates for both ions. Consequently, NF power consumption is lower than RO. As the biggest challenges facing the RO technology are the high electricity consumption, the use of NF as a pre-treatment in seawater desalination could be a prerequisite solution. In our ongoing work, a comparison between the RO and a combined system between both the nanofiltration and RO might give more detailed data about the economic feasibility of this technique.

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