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Research Article

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Desalination of Brackish Water Using Low Pressure Nanofiltration Membranes: Comparison and Simulation

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ABSTRACT

In the south Mediterranean countries and especially the North Africa, the water demands, since many decades, have increased while the conventional water availability has decreased dramatically. These trends continue. The obligation to use other non-conventional water resources such as desalinating water or waste water reuse becomes a necessity. Nanofiltration is a membrane process that competes with reverse osmosis for desalination and the removal of specific inorganic contaminants. The focus of the present study is to compare the performances of Nanofiltration membranes for the desalination of the brackish waters in heavily loaded in sodium and chloride contents and to simulate the maximum of the number of modules in pressure tube using the pressure tube configuration. Three commercial NF membranes were tested at different running conditions such as (pressure and type of configuration). The tested parameters were: Salt rejection (TDS), chloride, sodium, Flux rate (L/m.hr), permeability (L/m^2.hr.bar) and Flux recovery rate.

Keywords: Desalination; Brackish water; Nanofiltration membranes; Comparison; Simulation

INTRODUCTION

Water scarcity continues to challenge population around the world especially those living in areas that considered as arid or semi-arid regions like Moroccan country. As part of this region, the sud of Moroccan suffers from water scarcity, as the reliable water source for domestic, agricultural and industrial supply [1-3]. Desalination is a considerable alternative for water supply in order to alleviate the stress on the aquifer and to improve the quality of water in the area. So, desalination plants began to be established in Morocco using RO technique since 1975 [4]. Despite the fact that inverse osmosis is rapidly increasing worldwide thanks to scientific and technological advances, but he still requires an intensive pre-treatment to prevent membrane fouling, and high energy consumption. However, the challenge is in minimizing the high operational costs and energy consumption as well as quality improvement.

In this context, several studies have been devoted that the nanofiltration process can be an alternative to reverse osmosis for brackish water desalination [5-7]. The principal properties of the nanofiltration membranes are due to their remarkable ability, to selectively reject of different dissolved salts with high rejection of low molecular weight and dissolved components. In addition, the nanofiltration membranes can provide high water flux at low operating cost and low energy consumption [8-11]. The aims of this work is to studies the efficiency of nanofiltration process in production of potable water from brackish water in heavily loaded in sodium and chloride contents and to simulate the maximun of number of modules in pressure tube using a the pressure tube configuration. The study was conducted on an industrial pilot plant (supplied by the French Company TIA), having two modules equipped with three spiral commercial membranes (Filmtec NF90, NF270 and TR60). The water parameters were followed as a function of the running conditions (time, pressure) in order to follow the behavior of the membranes tested and to simulate the maximum number of module in the pressure tube for each membranes tested.

EXPERIMENTAL SECTION

Characteristic of Feed Water

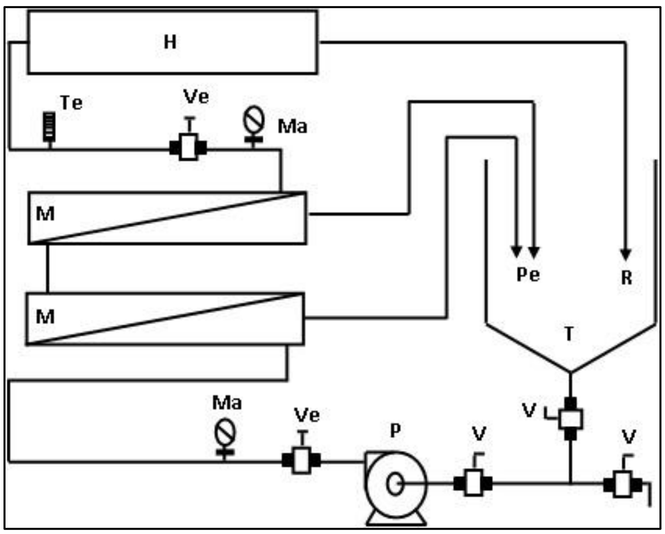
The characteristics of brackish water are shown in Table 1.

Table 1: Characteristics of brackish water

Parameters	Brackish water	Normes Marocaines	Normes OMS
T°C	23	-	25
pH	8.08	6.0 - 9.2	6.5-8.5
TDS ppm	2690	<1000	<1000
Na^+ppm	780,12	100	<200
Cl^-ppm	1325	350 - 750	<250
Mg^{2+}ppm	87,50	100	<50
Ca^{2+}ppm	20	<500	<270
SO_4^{2-}ppm	125,88	200	<200

Pilot Plant

NF and RO experiments were performed an industrial pilot NF/RO (E3039) provided by the company TIA (Applied Industrial Technologies, France) (Figure 1). The applied pressure over the membrane can be varied from 5 to 70 bar with manual valves. The operations were designed in a continuous simple pass mode and shown in Figure 2. The pilot is equipped with two identical modules in series. The pressure drop ΔP is about 2 bars. The two spiral wound modules are equipped with two commercial reverse osmosis and nanofiltration membranes. Table 2 gives the characteristics of the used membranes.



T : tank; P : feed pump; Ve : pressure regulation valves; V : drain valves;M : NF/RO module; Pe : Permeate recirculation; R : Retentate recirculation; H : Heat exchanger; Ma : Pressure sensor; Te : Temperature sensor

Figure 1: Diagram of the NF/RO pilot plant

After the run, membranes were cleaned with alkaline and acidic cleaning solutions according to the manufacturer's recommendation.

Table 2: Characteristics of the used membranes

Membrane	Cut	area (m^2)	P max (bar)	pH	Max temp (°C)	Materials	[Cl_2] tolerance ppm
NF90-4040 (Filmtec)	90 Dalton	7.6	41	3 à 10	45	polyamide	0.1
NF270-4040 (Filmtec)	270 Dalton	7.6	41	3 à 10	45	polyamide	0.1
TR60-4040 (Toray)	400 Dalton	7	10	3 à 10	45	polyamide	0.1

Tested Configuration

Figure 2 shows the scheme of the configuration tested. The permeate is recuperated while the retentate is recirculated to the tank of alimentation. Water supply equal to. This configuration has the advantage to follow the membrane performances with the TDS increase in the feed water, the flow of the permeate is maintained continuously.

This configuration has the advantage to follow the membrane performances with the TDS increase in the feed water, also to know the maximum conversion rate of treatment experimentally and to simulate the number of modules in pressure tube.

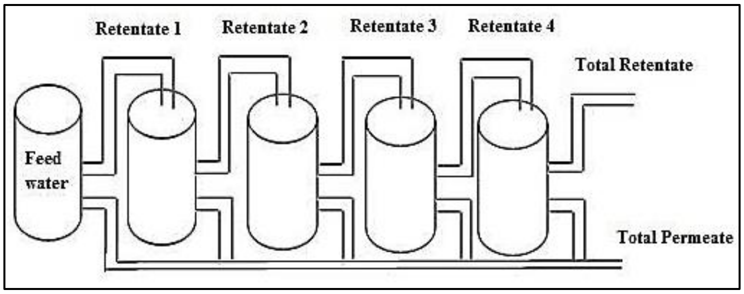


Figure 2: Configuration of pressure tube

Tested Parameters

The experiments were performed at 29°C. Samples of permeate were collected and the water parameters were determined analytically following standards methods such as:

- Conductivity (µs/cm) and temperature of samples were measured online using a conductivity meter (712 Conductometer, Metrohm AG, Switzerland).
- pH were quantified by a pH-meter (654 pH-meter, Metrohm AG, Switzerland) equipped with a glass electrode.
- Contents of chloride and sodium (ppm).
- Langelier index (IL).
- Flow rate: represents the volume of liquid passing through specific area of the membrane at certain operating pressure during a period of time, using the following formula:

$$Fluxrate = \frac{V}{t}(\frac{l}{m^2}.h)$$

Where, V: volume of water; (L): permeated at the time (t); A: surface area of membrane; t: time of filtration (s).

- Recovery rate: measures the ratio of treated water to feed water and used to describe the membrane performance. As there is no out for concentrate in our lab scale system, the flux recovery rate will be measured as indication of recovery rate. The following equations were used in calculating the flux recovery rate.

$$\%R = \frac{J_0 - J_P}{J_0} \times 100$$

Where, J_0: Flow of initial pure water (l/h); J_p: Flow of the produced water (l/h)

- The maximal recovery rate: is defined as the ratio of the produced water and of the feed water, it is calculated by the following equations:

$$TC_{max} = \frac{\sum_{n=1} J_P}{J_0} \times 100$$

Where, J_0: Flow of initial pure water (l/h); J_p: Flow of the produced water (l/h)

RESULTS AND DISCUSSION

These results illustrate the comparison of the performances of the three Nanofiltration membranes used (NF90, NF270 and TR60). The experiments were carried out at 10 bars of pressure. Figures 3-9 show the effect of the number of modules on the several analysis parameters.

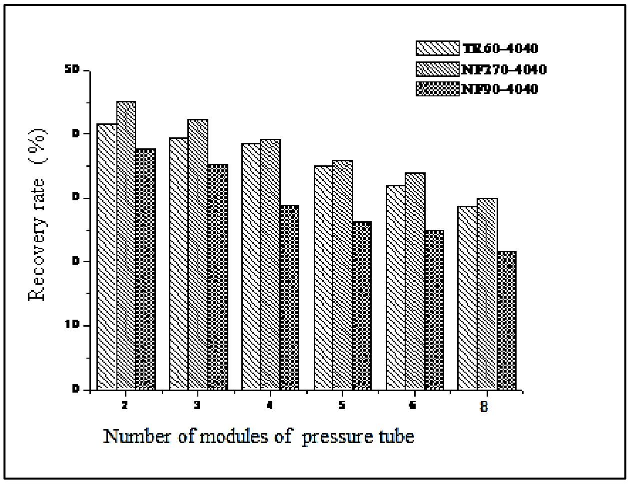


Figure 3: Effect of the number of modules on the recovery rate

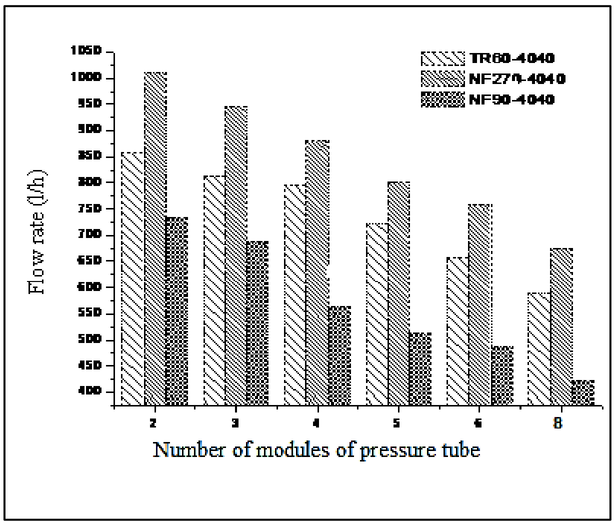


Figure 4: Effect of the number of modules on flow rate in permeate for the three tested membranes

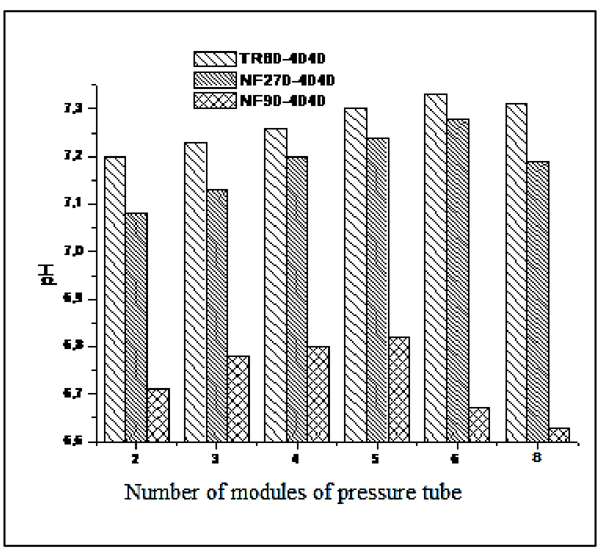


Figure 5: Effect of the number of modules on the pH in the permeate for the three testes membranes

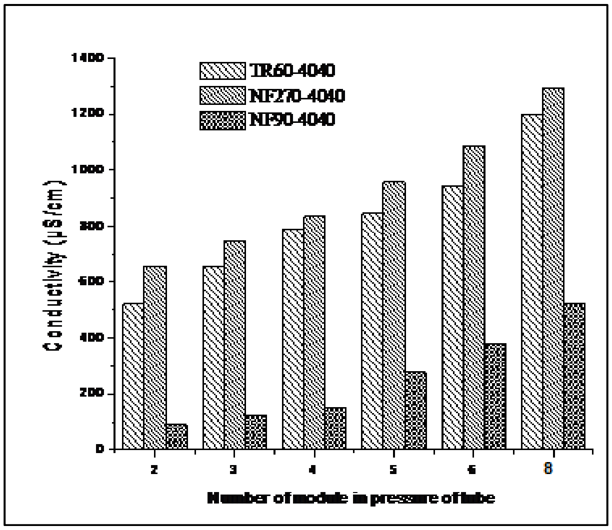


Figure 6: Effect of the number of modules on the conductivity in the permeate for three tested membranes

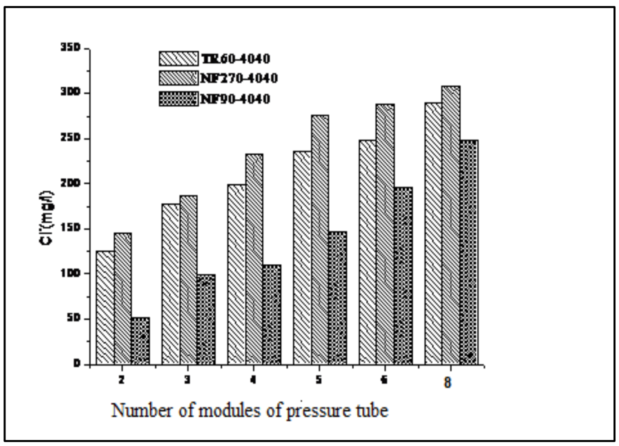


Figure 7: Effect of the number of modules on the chloride content in the permeate for three tested membranes

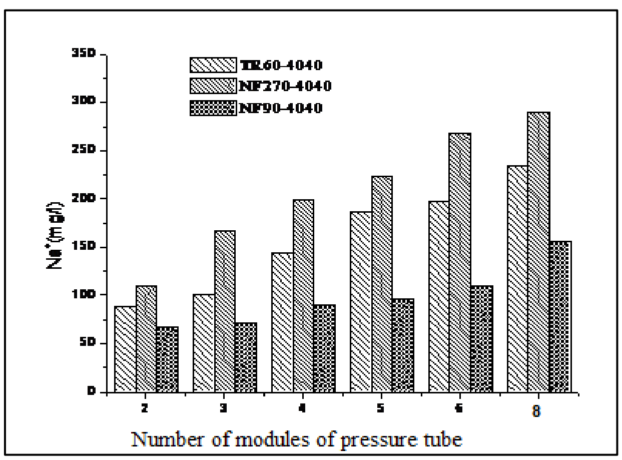


Figure 8: Effect of the number of modules on the sodium in the permeate for three tested membranes

The analysis of the results shows that the:

- The recovery rate decreases after each module (n = 2) in the separation process by the requirement of increasing the salt content in the feed water (retentate to be recycled), consequently the flow rate decreases periodically.

- The pH in the permeate increases slightly with increasing the number of modules, following the increase of the salt content in the feed water.
- In the retentate and the pH increases, and reaches a maximum for the three membranes tested.
- The conductivity and the salt of content increases in the total permeate, feed water and retentate with the increase of the number of module.
- The quality of the produced water is satisfactory and it is below the values recommended by WHO for NF90 membrane, idem for the values of Na^+ and Cl^- are is below the recommended values according to 8 of the number of modules.
- For NF270, the values of Na^+ and Cl^- exceeded the recommended standard after the module n=5.
- The quality of water obtained by the membrane TR60 is good up to module number 6.
- The quality of the water obtained by the NF90 membrane is demineralized, the post remineralization is needed.

According to the results, Figure 8 gives the variation of total recovery and applied pressure on function of the number of modules of NF90 membrane.

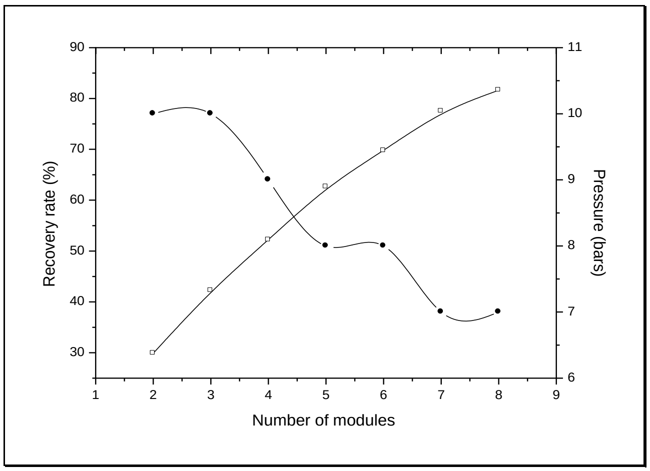


Figure 9: Effect of the number of modules on the total recovery rate and applied pressure

According to the Figure 9, the results shows that the total recovery rate increases but the applied pressure decreases with the increases of the number of modules. Although the total recovery decreased with increased feed salinity, these results can be attributing to the increase in osmotic pressure in the feed salinity. The maximum of the recovery rate is 80% at pressure value equal to 7 bars according to 8 of modules of the pressure tube.

CONCLUSION

This work shows the best performances of the nanofiltration process in brackish water treatment for the production of drinking palatable water. However, the obtained results show clearly the difference of the behaviour between the tested membranes. All the parameters such as the content of Na^+, Cl^-, Conductivity, and recovery rate decrease with the increase of the modules of pressure tube, but the total recovery rate decreases and thus, the quality of the produced water by NF90 is satisfactory; it is below the values recommended by WHO under following conditions. So, the results of simulation indicate that the maximum of the number of modules of the tube equal to 8 for NF90. In despite the remineralisation step is needed. The NF270 membrane is not able to fulfill the recommended drinking water; additional treatment is required before distribution, and the quality of water obtained by the membrane TR60 is good up to module number 6. In the conclusion, the NF90 membrane shows the best performances in brackish water desalination compared with TR60 and NF270.

ACKNOWLEDGEMENTS

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