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Comparison of the technical performances of three commercial membranes in desalination of brakish waters by reverse osmosis

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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. The desalination of various synthetic brackish waters by reverse osmosis was conduced using an industrial pilot plant. The influence on the desalination performances of many runing parameters such as pressure, recovery rate and salinity was studied. The performances of three commercial membranes in salt rejection were compared.
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KEYWORDS

Desalination;
Reverse osmosis;
Permeability;
Salt rejection.

INTRODUCTION

Desalination provides a sustainable source of fresh water for countries with limited water resources. Reverse osmosis(RO) process is increasingly being used for desalination of brackish and sea waters. Nowadays the desalinated sea and brackish waters by this technology exceed those by competitive technologies especially thermal processes.

The capacity of the desalination plants by RO was considerably increased from approximately some hundreds m^3/d to values higher than $300,000 m^3/d$ and will reach $500,000 m^3/d$ such as in Australia, Spain or Algeria. This is achieved among others through the rapid progress in the development of membrane technologies and energy recovery. This progress is on the basis of the wide use of the RO in the urban and industrial domains worldwide. Besides the production of the drinking water and the process water, this technology can be used for the waste water treatment[8,4]. This technology has also great potential in treatment of drinking water supplies containing undesirable dissolved species[5,9], and it has been established as a proven separation process in the chemical industry over the past two decades. Pervov et al.[6] reported that for treatment of groundwater having excessive hardness and concentration of iron, strontium, nitrates, fluoride, TDS etc., membrane treatments especially RO are more ad-

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vantageous than conventional treatments, as there are based on simultaneous rejection of all types of ionic and molecular species by semi-permeable membranes.

Morocco is characterised by a semi arid climate and in spite of the efforts which were accomplished in the construction of dams(Morocco has today some 103 dams for approximately 16 billion/m^3), the availability of water decreases with the years. The availability of water is now about 750m^3/capita/y and it will be just about 500m^3/capita/y in 2020, corresponding to a shortage situation. The obligation to use other non conventional water resources such as desalinating water or waste water reuse becomes a necessity. In this field, the big progress in Morocco in the water management since the beginning of the last decade, is the use of desalination in spite the relatively high cost per cubic meter. Considerable efforts were mobilised in the south with the construction of several desalination plants especially by National Office of Potable Water(ONEP) and the Cherifien Office of Phosphates(OCP). The national production capacity by desalination today exceeds the 35.000 m^3/day and will increases rapidly[1].

This work report on the study of the desalination of various synthetic brackish waters by reverse osmosis. The performances of three commercial membranes in salt rejection were compared under various runing condictions. The studies were carried out on an industrial pilot plant.

EXPERIMENTAL

The experiments were performed on an RO/NF pilot plant(E 3039) supplied by TIA Company (Technologies Industrielles Appliquées, France). The operations were conduced in a simpl pass mode as it shown in figure 1. The applied pressure over the membrane can be varied from 5 to 70 bar with manual valves.

The pilot plant is equipped with two identical modules operating in series. Each module contains one element. The pressure loss is about 2 bar corresponding to 1 bar of each module. The two spiral wound modules are equipped with two commercial reverse osmosis membranes. TABLE 1 gives the characteristics of the used membranes.

The experiments were performed at 25^{0}C. Samples of permeate, retentate were collected and water parameters were determined analytically following standard methods[7,2,3]. The followed parameters are:

- Permeate flow
- Salt rejection (R%)

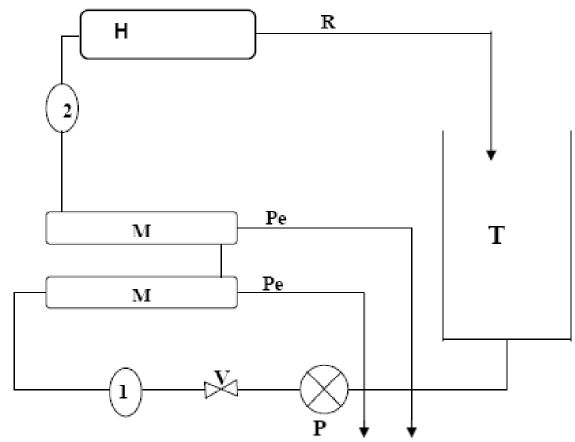


Figure 1: Diagram of the reverse osmosis pilot plant. T:tank; P:feed pump; V:pressure regulation valves; M:Reverse osmosis module; Pe:Permeate recirculation; R:Retentate recirculation; H:Heat exchanger; 1:Pressure sensor; 2: Temperature sensor

TABLE 1: Characteristics of the used membranes

Membrane	Surface (m^2)	P max (bar)	pH	Max temp (°C)	Materiels	[cl_2libre] tolerance ppm
BWTMG10 (FILMTEC)	8.1	25	2a 11	40	polyamide	0.1
TM710 (TORAY)	7.2	41	2a 11	45	polyamide	0.1
BW30LE4040 (FILMTEC)	8.1	41	2a 11	45	polyamide	0.1

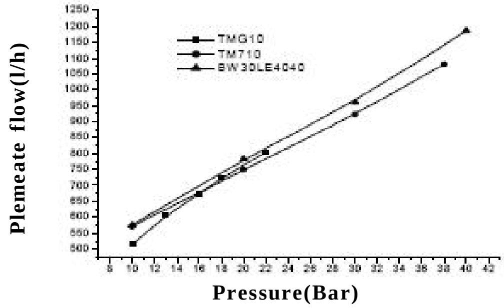
TABLE 2: Characteristics of the feed water

Salinity (g/l)	pH	γ(mS/cm)
2	6.19	4.01
4	6.02	7.82
6	6.3	11.4
8	6.44	14.98
10	6.62	18.46

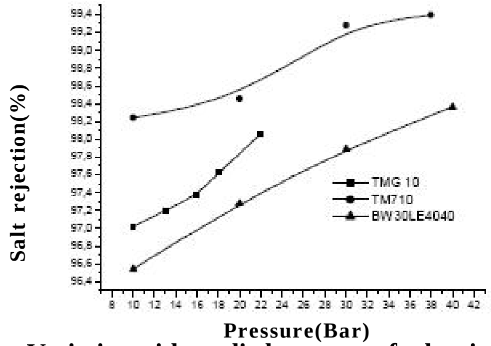
To compare the performances of different membranes, experiments were carried out on synthetic water prepared from distilled water doped with NaCl at various concentrations: 2, 4, 6, 8 and 10ppm. The analytical results of the untreated water are shown in TABLE 2.

RESULTS AND DISCUSSION

In this work, the performances of three commercial membranes in salt removal are compared for vari-

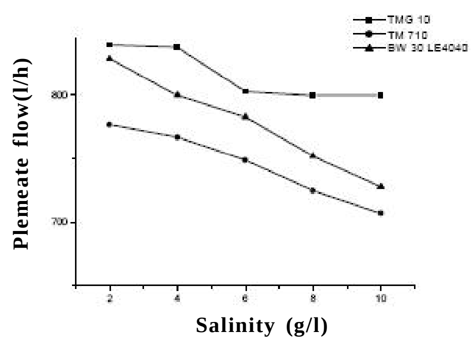


Variation with applied pressure of permeate flow

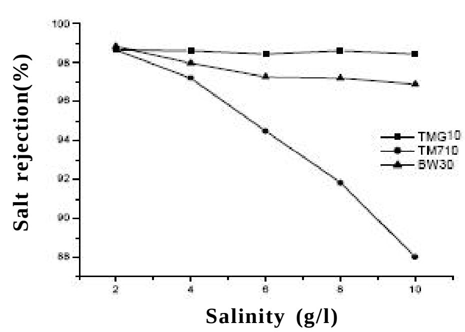


Variation with applied pressure of salt rejection

Figure 2: Variations with applied pressure of permeate flow and salt rejection



Variation with salinity of the permeate flow for the three tested membranes



Variation with salinity of the salt rejection (%) for the three tested membranes

Figure 3: Variation of the permeate flow and of the salt rejection

ous running conditions of the pilot plant. The influences on salt removal of pressure, salinity and of recovery rate are followed. For the influence of pressure and salinity, the recovery rate was fixed at 30%.

Influence of pressure

The experiments were carried out for a recovery rate of 30%. The imposed pressures were: 10,13,16,18 and 22 bar for TMG 10,10,20,30 and 38 bar for TM710 and 10,20,30 and 40 bar for BW30LE4040. Following the constructor instructions, the maximal pressure supported by the TMG10 is 25 bar. The tested salinity was 6g/l.

Figure 2 gives respectively, the variations with applied pressure of permeate flow and of salt rejection (conductivity %) for the three membranes and for a salinity of 6g/l.

For the three tested membranes, the permeate flow increases with the applied pressure and reaches a level following the phenomenon usually observed in reverse osmosis and nanofiltration and according to the known relation between the flow, the applied pressure and the osmotic pressure. It was observed also that the permeate conductivity decreases with increasing the applied pressure.

For the fixed conversion rate, the salt rejection increases with the applied pressure for each tested membrane. These results can be attributed essentially to the increase in the solvent flow. Owing to the fact that the salt transfer does not follow the same variations of solvent, the salt becomes divided in a more important volume of solvent and the permeate will be less concentrated, i.e. the salt rejection would be more important.

Influence of salinity

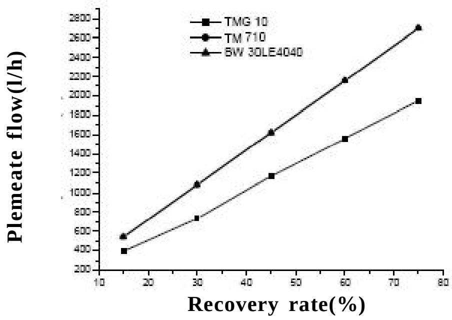
The experiments were carried out at a fixed pressure of 20 bar and for four salinities: 2,4, 6,8 and 10g/l. Figure 3 gives the variation of the permeate flow and of the salt rejection for the three tested membranes.

The decrease of the permeate flow with increasing salinity for the three tested membranes, can be attributed essentielly to the the increase of the osmotic pressure.

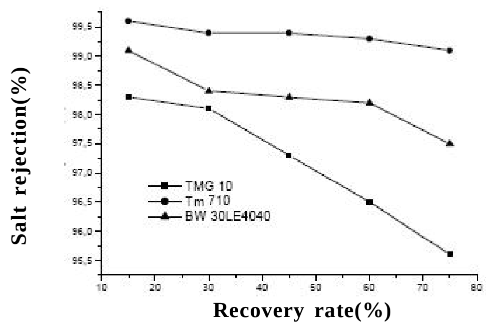
The decrease of the salt rejection with increasing salinity is a common phenomenon observed in reverse osmosis and nanofiltration. The increase of the osmotic

TABLE 3: Permeate flow and salt rejection for the three membranes and various salinities

Pressure/Membrane		10 bar		20 bar		30 bar	
		Permeability (l/hm²)	Salt rejection(%)	Permeability (l/hm²)	Salt rejection(%)	Permeability (l/hm²)	Salt rejection(%)
TM710	2g/l	41.67	98.33	53.96	98.86	66.25	98.77
	6g/l	39.65	98.24	52.01	98.45	63.96	99.28
	10g/l	37.99	98.06	49.10	98.45	62.22	98.80
TMG10	2g/l	32.53	98.33	51.79	98.68	-----	----
	6g/l	31.79	97.02	49.51	98.43	-----	----
	10g/l	31.79	96.38	49.38	98.45	-----	----
BW30LE4040	2g/l	37.04	98.63	51.17	98.85	62.35	99.05
	6gL	35.49	96.54	48.33	97.28	59.26	97.89
	10g/l	31.73	96.51	44.94	96.72	57.90	97.13

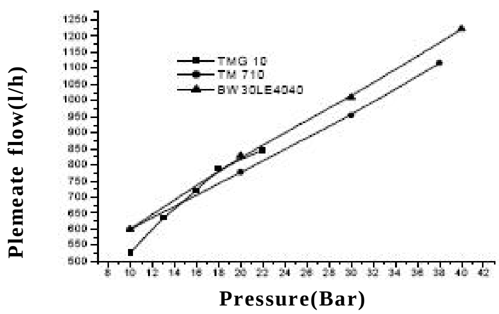


variation with recovery rate of the permeate flow for the three tested membranes

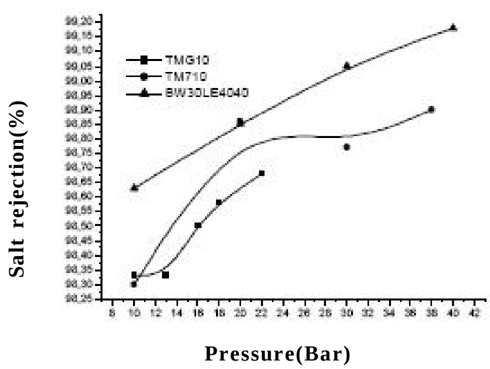


Variation with recovery rate of the salt rejection (%)

Figure 4: Variation with recovery rate of the permeate flow and of the salt rejection

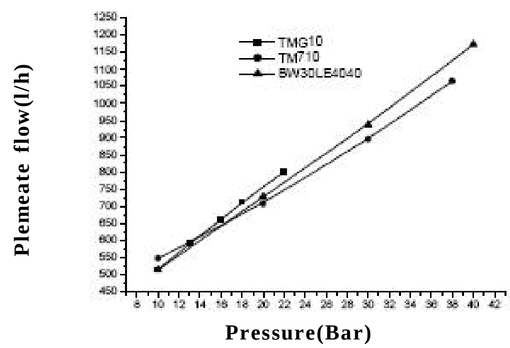


Variation with applied pressure of permeate flow

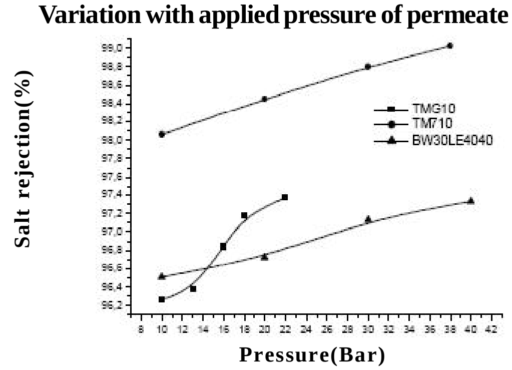


Variation with applied pressure of salt rejection

Figure 5 : Variation with applied pressure of permeate flow and salt rejection for salinity of 2g/l



Variation with applied pressure of permeate flow



Variation with applied pressure of salt rejection

Figure 6: Variation with applied pressure of permeate flow and salt rejection for salinity of 10g/l

pressure leads to the decrease of the effective pressure on the membrane, and to the decrease of the solvent flow. The salt is transferred in a small volume of solvent, and the permeate becomes more concentrated, i.e. the salt rejection would be less important.

Influence of recovery rate

The experiments were carried out for a salinity of 6g/l. The fixed pressure was 20 bar for TMG10 and 40 bar for TM710 and BW30LE4040. Figure 4 shows, for the three tested membranes, the variation with recovery rate, of the permeate flow and of the salt rejection.

The increase of the permeate flow and the decrease of the salt rejection with increasing the recovery rate are a predictable phenomena. With increasing the recovery rate, retentate flow decreases and consequently the ion concentrations on the side of the solution to be treated becomes important. This leads to the increase in transfer of ions through the membrane, i.e. to the decrease in salt rejection.

CONCLUSION

The variations with the applied pressure of the permeate flow and salt rejection for the three tested membranes and for various salinities 2,6, and 10g/l are given in TABLE 3 and figures 2, 5 and 6. The recovery rate was fixed to 30%.

For the three salinities and the various applied pressure, the higher permeability is obtained with the membranes TM710. The permeability of the BW30 LE4040 and the TMG10 membranes are practically the same.

For the two higher salinities(6 and 10g/l), the salt rejection increases in the following direction: TM710 >TMG10>BW30 LE4040. This order is reversed compared to the permeability which is predicted.

For the low salinity(2g/l), the order is as follows: BW30 LE4040>TM710>TMG10. This contradiction with the preceding results can be attributed among others to the concentration polarization which is accentuated with the weak concentrations.

The technical choice between the three membranes depends rather on the salinity of the raw water. The osmotic pressure corresponding to the three salinities are respectively: 1.69, 5.07 and 8.46 bar. Industrially, the recommended pressure must be about the twice of the osmotic pressure: 4,10 and 17 bar. So, for the salinity of 2g/l and the recommended pressure, the best permeability and the best salt rejection are obtained with the BW30 LE404 membrane. However the minimal pressure recommended by the manufacturer for this membrane is of 10 bar. At this pressure the membrane BW30 LE4040 remains more performed than the two other membranes. For 6 and 10g/l the best perform ances are obtained with the TM710 membrane.

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