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Comparison of the Performances of Two Commercial Membranes in Demineralization by Nanofiltration. Continuous Mode

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ABSTRACT: *In this work, comparison of the performances of two commercial membranes in demineralization of drinking water of M'rirt city (conductivity 2140 µS/cm) by nanofiltration in continuous mode was carried out. The pilot used (supplied by the French Company TIA, Techniques Industrilles Appliquées) is an industrial nanofiltration pilot plant having two modules equipped with various spiral commercial membranes with an area of 7.6 m^2. Two configurations were tested: simple pass and supplied batch configuration. The water parameters were followed as a function of the running conditions (time, pressure) in order to follow the behaviour of the membranes tested.*

Keywords: *Desalination, Nanofiltration, Recovery rate, Pressure, Membrane*

I. Introduction

Water, a vital element for humans, is the natural beverage with excellence. It can be drunk in abundance within the limit of 1 to 2 liters daily. But access to clean water and good quality is still lacking especially in arid areas and some rural areas.

Supplying the population with drinking water quality meets standards or WHO guidelines remains for governments' paramount concern.

With the development of urbanization and changing consumption patterns, the demand for water is changing dramatically in terms of quantity and quality.

Located in the eastern part of central Morocco, near the western edge of the Middle Atlas Causse M'rirt, a small town located at 1113 m above sea level, is halfway between Azrou and Khénifra; it is also connected to Meknes by road Adarouch.

The city of M'rirt had in 2004 a total population of 35.196 inhabitants. The population increased from 13.856 inhabitants in 1982 to 25.942 inhabitants in 1994, this fairly rapid increase in population has led to think a source of drinking water because of insufficient quantities of water supplied to it the national Office of water and electricity (ONEE-MOROCCO) constructed a station of water treatment of Oued Oum Errabia to supply the city of M'rirt by drinking water. The salinity of the city of M'rirt varies during the year. So, ONEE have initiated study in collaboration with Ibn Tofail University to investigate remedial options.

The nanofiltration (NF) is a membrane technique placed between reverse osmosis (RO) and ultrafiltration (UF). This technique has been developed through improved materials, which provides many possibilities/opportunities significantly higher than the RO. Currently; use of nanofiltration is increasing for the water treatment and its application gradually replacing the areas reserved to RO like treatment of brackish water [1]. The NF uses two mechanisms of mass transfer (i) the convection force, as UF and (ii) the solubilization–diffusion as in RO. The differences in selectivity between ions are distinct in NF because of their strong dependence with regard to the operating conditions (transmembrane pressure, conversion rates, and salinity) and intrinsic properties of the membrane material (hydrophilic/hydrophobic, pore diameter, presence or absence of charge) [2]. The nanofiltration is an innovative process having many applications, especially for drinking water and wastewater treatment [3].

The purpose of this study is to compare and to follow the performances of two commercial membranes in demineralization by nanofiltration in continuous mode and following two configurations.

II. Experimental

The experiments were performed on an NF/RO pilot plant (E 3039) supplied by TIA Company (Technologies Industrielles Appliquées, France). The operations were conducted in a continuous mode as is shown in Fig.1. The applied pressure over the membrane can be varied from 5 to 70 bars 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 configurations tested are: simple pass and supplied batch configuration.

The two spiral wound modules are equipped with two commercial nanofiltration membranes of one type. Table 1 gives the characteristics of the membranes used.

Table 1
Characteristics of the membranes used

Membrane	Cut off (Da)	Surface (m^2)	Material	Manufacturer
NF90*4040	90	7.6	Polyamide	Filmtec Dow
NF270*4040	270	7.6	Polyamide	Filmtec Dow

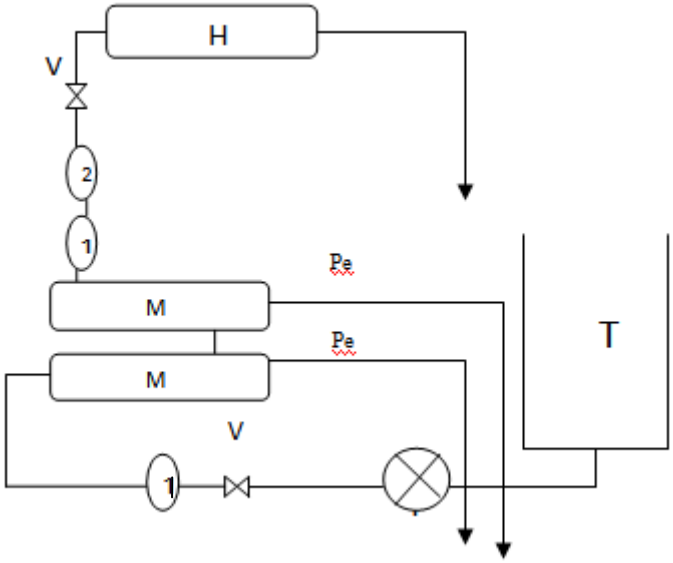


Fig.1: Diagram of the nanofiltration pilot plant. T: tank; P: feed pump; V: pressure regulation valves; M: nanofiltration module; Pe: permeate recirculation; R: retentate recirculation; H: heat exchanger; 1: pressure sensor; 2: temperature sensor.

The experiments were performed at 30 °C. Samples of permeate were collected and water parameters were determined analytically following standard methods.

- *Determination of chloride ions*

Determination of Chloride by the volumetric method mercuric nitrate. Chlorides were assayed in acid medium by mercuric nitrate in the presence of indicator: diphenylcarbazone.

- *Determination of sulphate ions*

The determination of sulphate ions was performed by the spectrophotometric method.

- *Determination of total hardness (total hardness)*

Analysis of the water hardness is based on the complexometric titration by the disodium salt of tetra acetic acid (sodium EDTA) in the presence of Eriochrome black T, freshly prepared as a color indicator of the buffer solution and ethylenediamine acid TH. The results are expressed in °F or in meq/l.

- *Determination of calcium ions*

The analysis of calcium ions is performed by complexometric titration. The sodium EDTA is used as titrating agent after adding the carboxylic acid calcone (calcon) and caustic soda. The results are expressed in mg/l.

- *Determination of sodium and potassium ions*

The analysis of sodium and potassium ions was carried out by atomic absorption spectrometry to flame.

- *Determination of TA and TAC*

The analysis of these parameters is carried out by a volumetric assay using hydrochloric acid as titrant phenolphthalein as a color indicator for TA and methyl orange as a color indicator for the TAC agent. The results are given in meq/l or in °F.

- *Conductivity*

The conductivity was measured by a conductivity measuring cell WTW 82362 cond 340i/SET adapted to a type conductivity Crison 522 Conductimeter kind.

- *Langelier Index*

The Langelier index expresses water quality by indicating its aggressiveness, it is expressed as follows:

$IL = pH-pH_s$

With pH: is the initial pH of the water and pH_s: the pH of saturation.

Where C_p and C_0 are respectively the permeate and initial concentration.

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

The experiments were conduced on water of M'rirt city. The analytical results of untreated water are shown in Table 2.

Table2: Characteristics of the feed water

Parameters	Feed water
pH	7.74
Conductivity, µS/cm	2140
Temperature, °C	29.0
MES, ppm	< 0.2
Turbidity, NTU	< 3
Cl^-, ppm	595.0
TA, °F	0.0
TAC ,°F	34.0
TH ,°F	34.65
Ca^{2+},ppm	105.6
Mg^{2+}, ppm	20.05
Na^+ , ppm	381
K^+ , ppm	3.8
SO_4^{2-} , ppm	60.0
pHs	7.52
Al^{3+}, ppm	0.12
Langelier index	+0.22

III. Results and discussion

3.1. Comparison of the performances of two commercial membranes in simple pass

A comparison of the performances of two commercial nanofiltration membranes in demineralization was carried out in simple pass configuration.

For the NF90 membrane, the feed rate is 1973 l/h at 10 bars, 2760 l/h at 15 bars and 3450 l/h at 20 bars corresponding respectively to a conversion rate of 38%, 40% and 42 %.

For the NF270 membrane, the feed rate is 2362 l/ h at 10 bars, 3459 l/h at 15 bars and 3880 l/h at 20 bars corresponding respectively to a conversion rate of 43%, 47% and 53 %.

The operations were conduced for a conductivity of feed water of 2140 µS/cm corresponding approximately to TDS of 1622 mg/l.

Fig.2 shows the variations as a function of pressure of the conductivity of the permeate and permeate flow for the two membranes. The conductivity of the permeate and therefore TDS are low in comparison with those of the water supply and this is more remarkable for the membrane NF90* 4040. The permeate flow rate increases with the pressure for the two membranes. The permeate flow of the membrane NF270 * 4040 is high relative to that of the membrane NF90* 4040 and this may be due to the high membrane permeability of the NF270*4040.

Fig.3 shows that the water quality is improved by the two membranes. This figure shows that:

- For the membrane NF270*4040, the pH of the permeate remains substantially close to that of the feed water and this for three pressures applied. The pH of the permeate for the membrane NF90*4040 is almost below standards drinking water.
- For the membrane NF90*4040, the content of all ions in the permeate is below standards drinking water, a remineralization of this water is obligatory. These results can be attributed to the nature of the membrane which is close to those of the reverse osmosis membrane properties. For the membrane NF270*4040, mineralization and hardness are satisfactory.

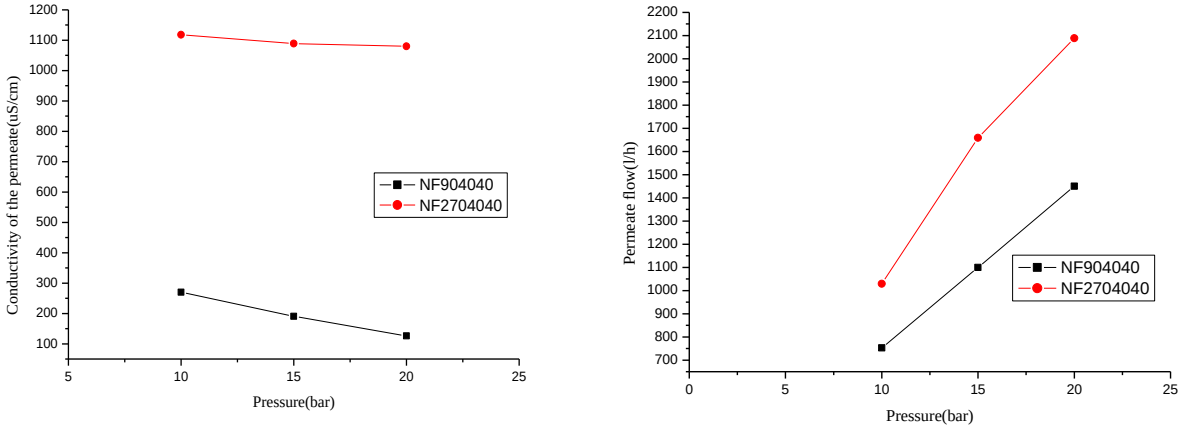
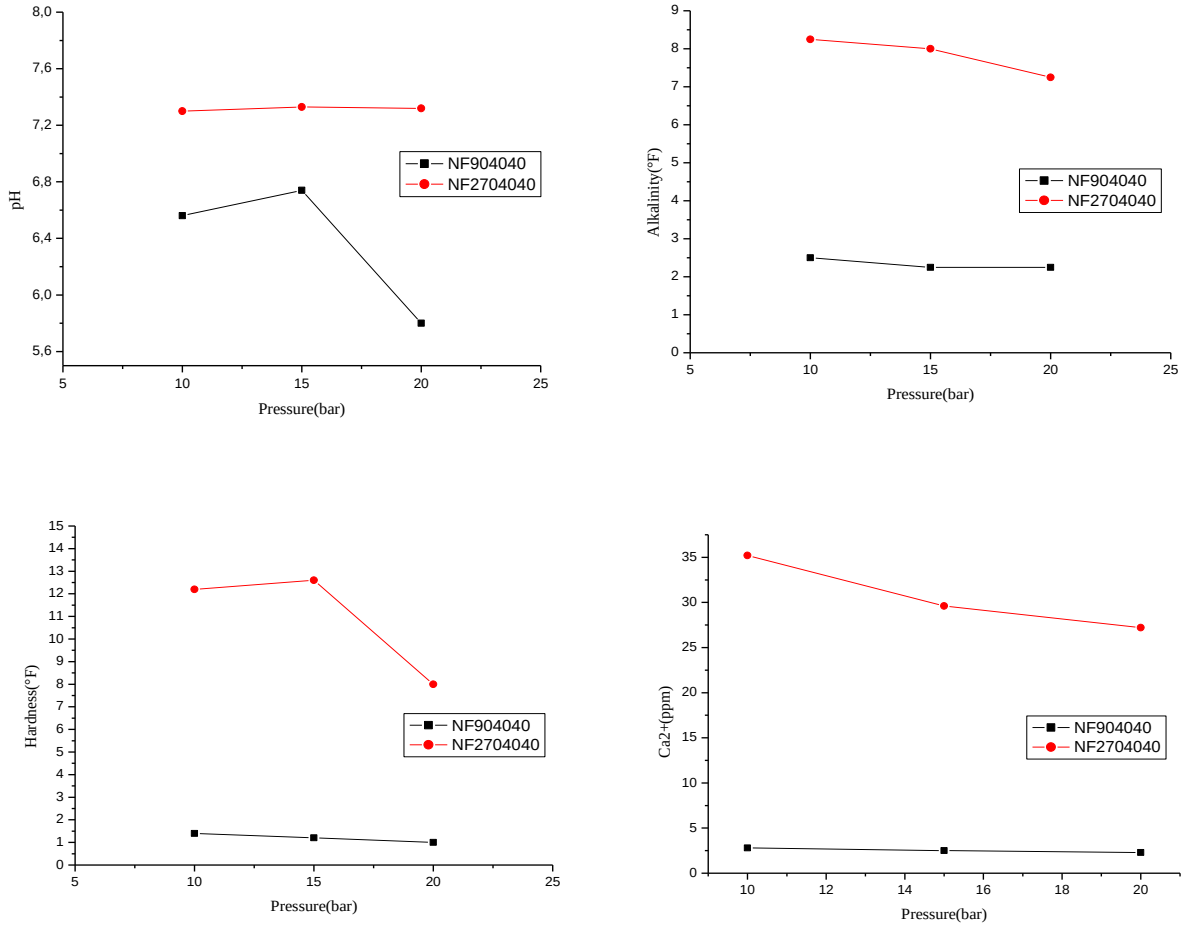


Fig.2: Variation with pressure of the conductivity of the permeate



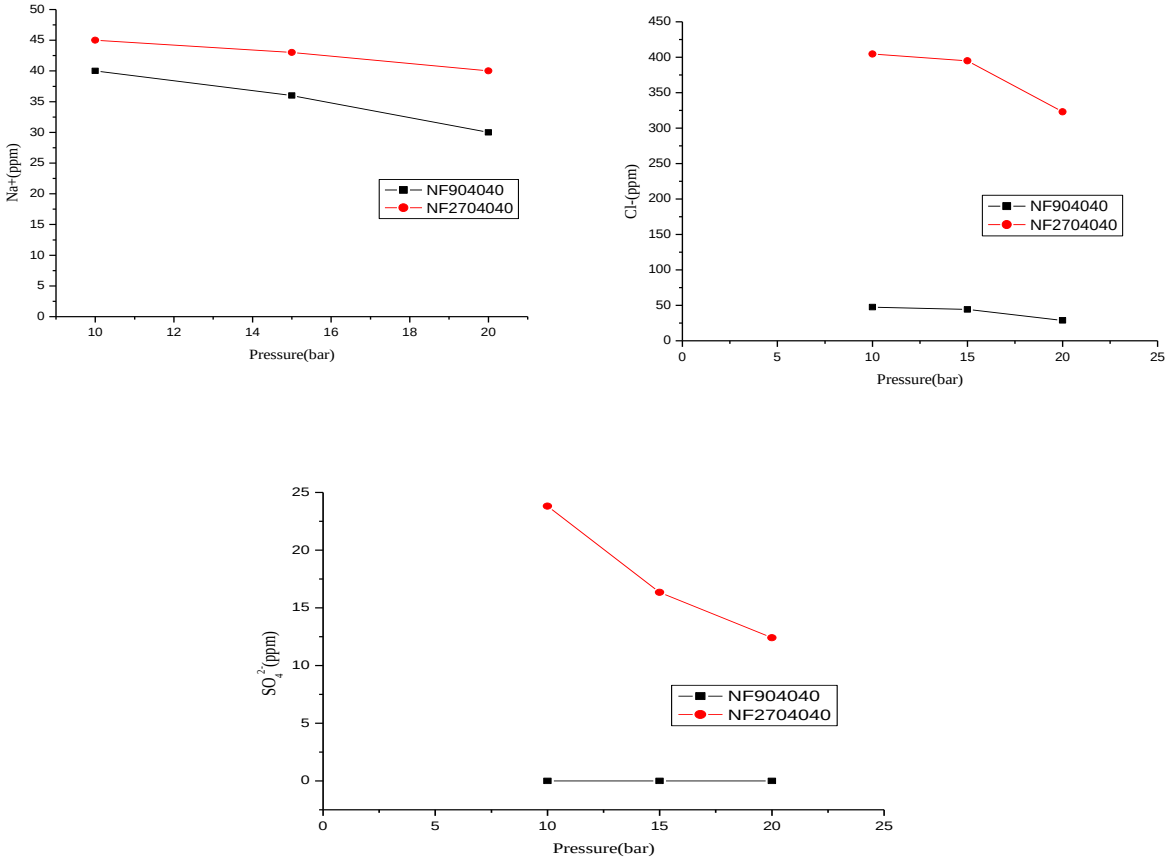


Fig.3: Variation with pressure of the permeate quality

3.2. Demineralization in supplied batch configuration

The behavior of the two membranes in demineralization was followed in a supplied batch configuration.

This configuration has the advantage to follow the membrane performances with the TDS increase in the feed water. Fig.4 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 the flow of the permeate is maintained continuously.

The recovery rate was fixed at 40%. To have the same initial permeate flow, the applied pressure was 10 bar for NF90*4040 and 6 bar for NF270*4040. Figure 5 gives the variation with time of the permeate flow for the two membranes.

These results show that that the decrease of the flow rate was more marked with NF90 membranes than with the NF270. This can be attributed, on one hand, to the low permeability of NF90 with regards to NF270 membrane, and, on the hand, to the high increase with time of the osmotic pressure in the case of NF90 membrane as it is shown in figures 6 and 7.

Figs.6 and 7 give for the two membranes the variations with time of conductivity, pH, alkalinity, hardness, sulphates, calcium, chloride and sodium contents in the permeate, the retentate and in the tank of alimentation.

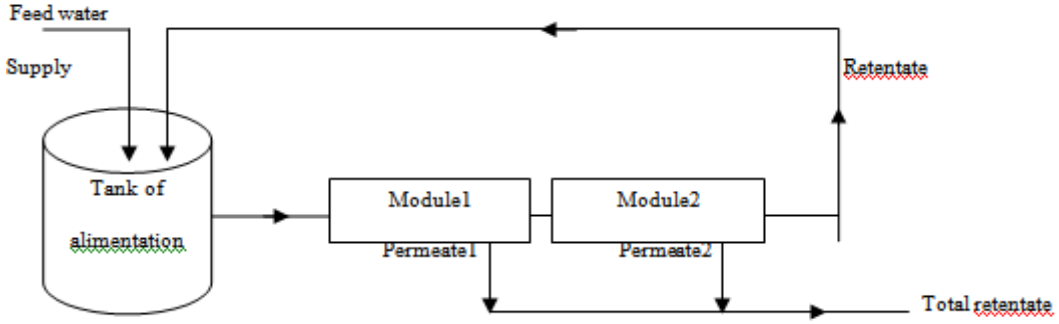


Fig.4: Diagram of operation of the test

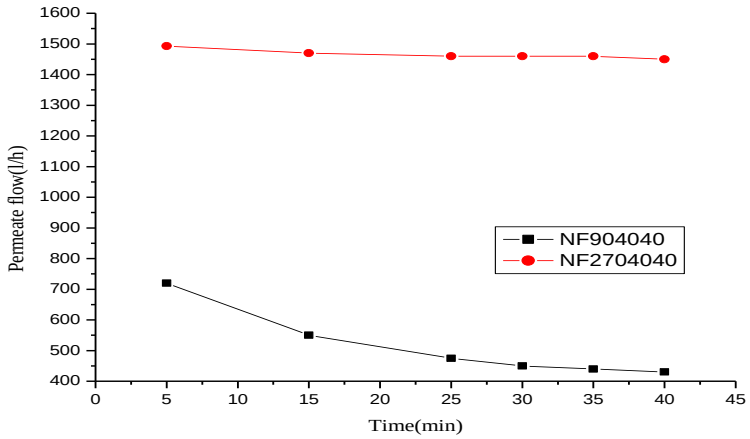
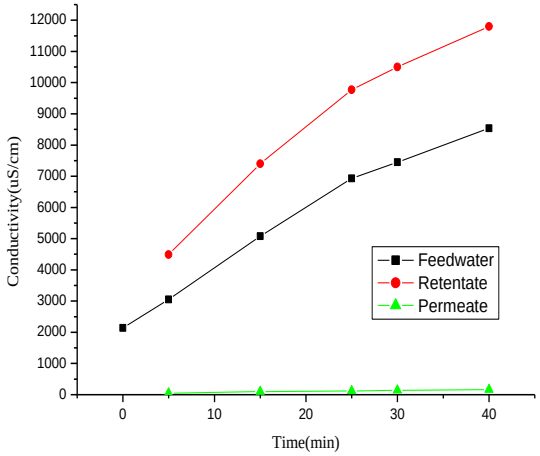
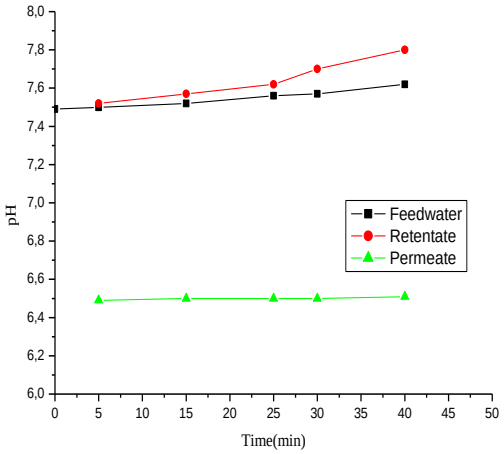
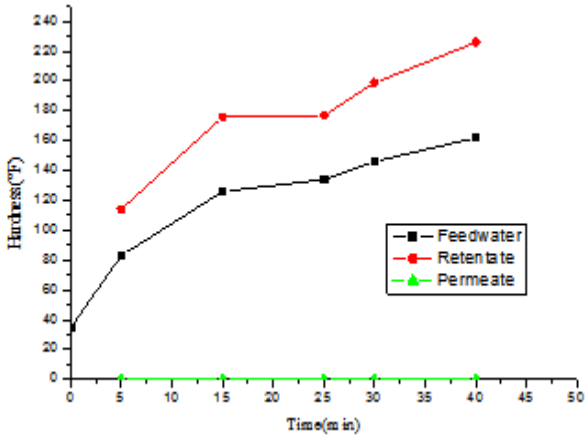
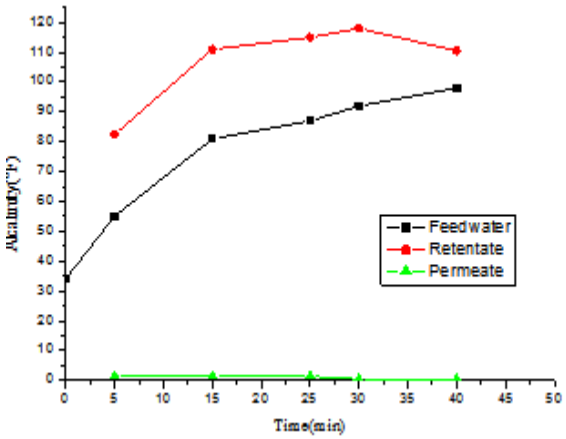


Fig.5: Variation with time of permeates flow









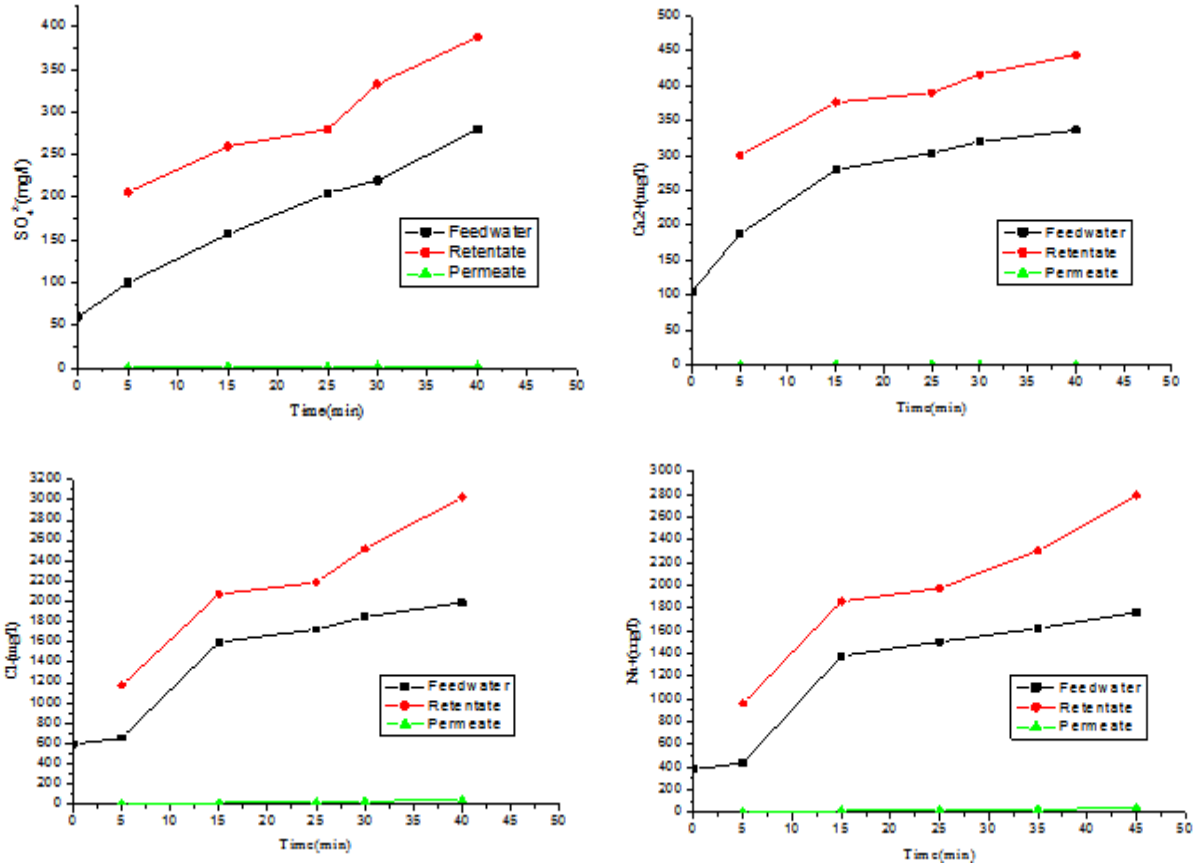
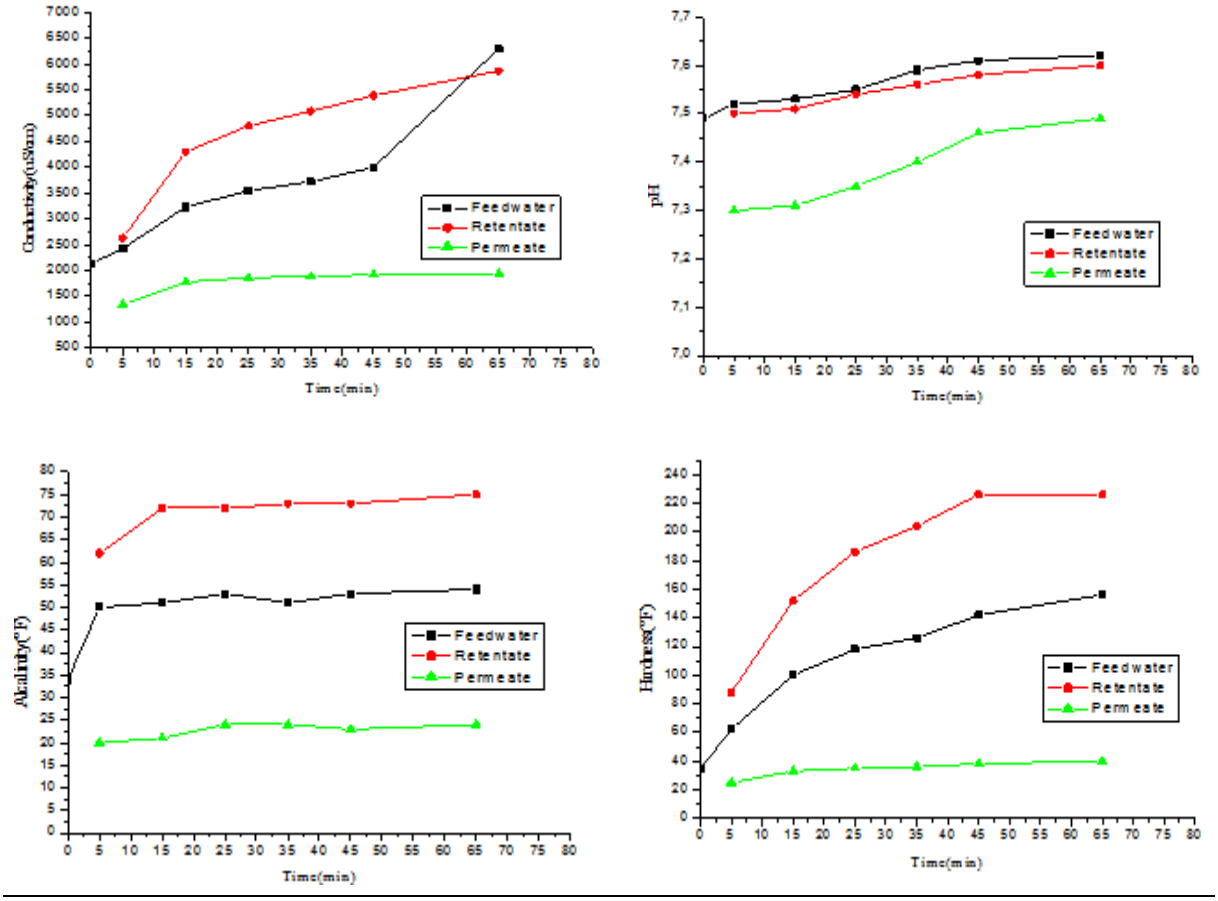


Fig.6: Variation with time of the water quality for NF90*4040



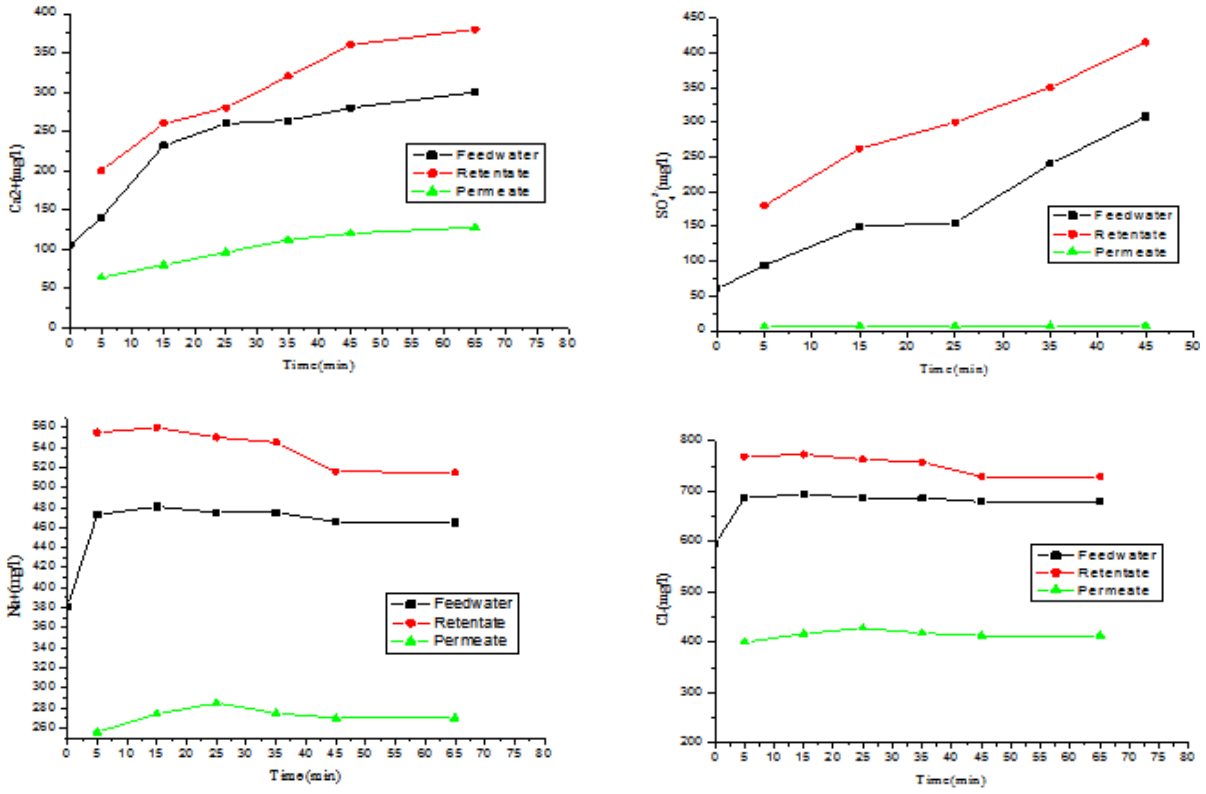


Fig.7: Variation with time of the water quality for NF90*4040

For NF90 (Fig.6) practically all the parameters remain constant with time, while the feed water parameters increase considerably. In the retentate precipitation occurs at 30min as it is shown in the curves of pH and alkalinity.

This precipitation was observed with naked eye at 40min. In the range of conductivity of the feed water studied, NF90 rejects practically all the ions.

For NF270 (Fig.7), the permeate conductivity increases with time to reach the level of 1940 µS/cm after 65 min according to the increase of the feed water conductivity. In fact the feed water conductivity increases with time and tends to a level after 65 min corresponding to a value of about 6300 µS/cm. No precipitation was observed in the retentate for the studied conductivity.

These results are attributed essentially to the nature of the two membranes.

IV. Conclusion

In this work, studies on the demineralization by nanofiltration were conduced on surface water of M'rirt city.

Comparison of the performances of two commercial membranes in demineralization by nanofiltration in continuous mode was carried out.

- The properties of NF90 membrane are close to reverse osmosis membranes.

The influence of the initial conductivity and therefore TDS on the demineralization has been studied.

In the salinity range of the treated water studied, practically all the parameters of the water quality are ameliorated by the NF operation especially the water salinity.

V. Acknowledgments

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