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Research Article

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Performances analysis of the reverse osmosis desalination plant of brackish water used for drinking water: Tagounite, Morocco

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ABSTRACT

This paper is concerning the performance evaluation of small size brackish water reverse osmosis desalination units. The plant consists of a brackish water intake, pretreatment, two stages of reverse osmosis membranes in two lines, post-treatment and product water storage tank, nominal capacity of 252 m3/d of drink water. In this study, some important design factors and operating conditions are reviewed and the plant operating data are used to evaluate the unit performances.

Keywords: Brackish water; Reverse osmosis; Desalination; Drinking water; Performance.

INTRODUCTION

Water, a limited finite resource, vital for the very existence of life on earth and a necessity for economic and social development and for environmental sustainability, is becoming a scarce commodity. This is caused by the population growth, the change of lifestyle, water pollution, inefficient use of water and climatic changes with more frequent extreme events such as droughts and floods. Where the availability of water cannot be increased by using conventional resources or by recycling or cannot be made available by demand management methods, the desalination of sea or brackish water offers an alternative solution [1-2-3]. The desalination of water has been practiced since ancient times but was not widely used due to technological limitations, the prohibitive high capital costs, high energy consumption and finally very high unit cost when compared to conventional water [4-5]. New technological advances in the last 30 years tremendously reduced the capital cost and the energy consumption so that desalination projects can be considered as alternative solutions to water development.

The southern provinces of Morocco are suffering from water shortage .This is due to the population growth and climate changes. However, some areas in Zagora province have brackish water with significant water resources to mobilize after recovery operations, with salinity from 3 to 6g/l. The National Office of Electricity and Drinking Water (ONEE) completed the installation of a demineralization plant by Reverse Osmosis in Tagounite, 60 km south of Zagora, with a salinity of 4 g/l. This study focuses on presenting this installation and evaluating its performances.

EXPERIMENTAL SECTION

2.1. Raw Water Characterization

The raw water, captured via a well catchment system and driven to the desalination plant of Tagounite, has the following average physical, chemical and microbiological characteristics which are typical of water of well and are summarized in **Table 1**.

The physico-chemical parameters of the raw water showed that the conductivity has a high value, and this is due to the high value of the levels of chloride ions, calcium and magnesium which exceed the Moroccan drinking water standards.

The conductivity of the raw water throughout the year varies between 4840 and 5300 µS / cm and a temperature of 23 °C to 30 °C. The chloride ions have a concentration ranges from 1178 to 1526 mg / l, and that of magnesium ions between 250 and 311 mg/l. Calcium ions have a concentration about 360 mg/l. The pH which takes the following values 7.12 to 7.28. Increased levels of these physico-chemical parameters annually lead to an increase of the conductivity of the raw water and consequently the TDS 3702 – 4040 mg/l (Total Dissolved solids).

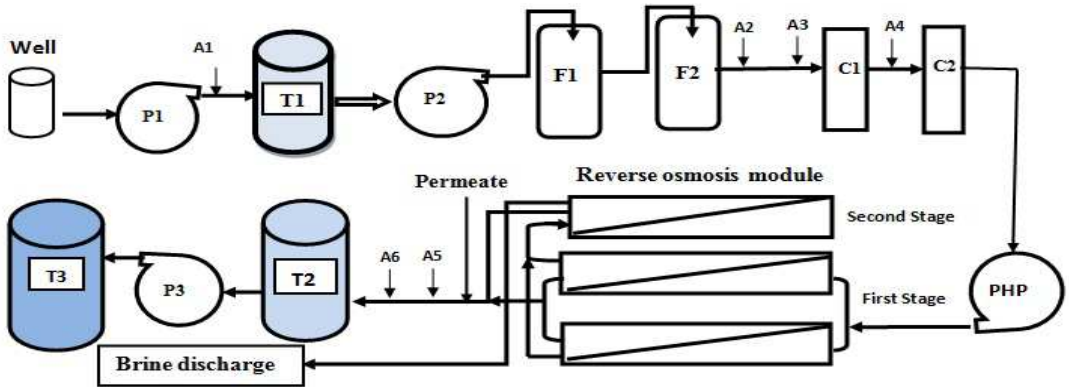
Table 1: Characteristics of the raw brackish water

	Physical-chemical characteristics	**Moroccan standards of drinking water**
T (°C)	23-30	-
PH	7,12-7,28	6.5-8.5
Turbidity, NTU		5
Conductivity µS/cm	4840 -5300	2700
TA méq/l	0	-
TAC méq/l	4-5,1	-
Oxydabilité mg/l	0,92-1,72	5
Fer mg/l	<0,1	0.3
Chlorure mg/l	1178 - 1526 / l	750
TH méq/l	36-42	-
Ca^{2+} mg/l	344-366	500
Mg^{2+}mg/l	227-293	200
TDS mg/l	3702 – 4040	1000-2000
	Microbiological characteristics	
Total colliforms UFC /100ml	0	0 /100 ml
fecal colliforms UFC /100ml	0	0 /100 ml
Fecal Streptococci UFC /100ml	0	0 /100 ml
Microorganisms at 22°C and 37 °C	0-3	20 /1 ml at 37°C 100 /1 ml at 22°C
Total colliforms UFC /100ml	0	0 /100 ml
fecal colliforms UFC /100ml	0	0 /100 ml

2.2. Description of the Reverse Osmosis plant

Tagounite Brackish Water Reverse Osmosis Plant (BWRO), started in July 2009, has a production capacity of 252m^3/d. This desalination plant is in the municipality of Zagora in the South east of the Morocco. The plant is fed with brackish water from wells located at 1 km far from Tagounite.

Figure. 1. Shows the diagram of the plant. As shown in this Figure, the raw brackish water coming from the wells flows into a Raw water Tank, then it is sent to the pretreatment unit (Sand filters followed by cartridge filters), and then to the RO modules using high pressure pumps. After, the permeate water is mixed with the raw brackish water. This mixture is stored in a reservoir.



(T_1: Raw water Tank (36m^3); T_2: Product water storage tank (26m^3); T_3: Reservoir Product water (200m^3); F1, F_2: Sand filter; C_1, C_2: Cartridge filters (5µm); P_1, P_2, P_3: Pump; PHP: High pressure pump; A_1: Calcium hypochlorite lime; A_2: Sulphuric acid A_3: Antiscalant; A_4: sodium metabisulfite; A_5: Sodium bicarbonate; A_6: Calcium hypochlorite lime)

Figure 1: Flow diagram for the Tagounite brackish water desalination plant

- **Pretreatment unit:** The raw brackish water is pretreated through the following stages:
- **Prechlorination**: A prechlorination due to the occurrence of biofouling on the RO membranes.
- **Acidification**: Sulphuric acid is injected at the inlet of the plant to prevent carbonate precipitation.
- **Sand filters**: Sand filter can treat a flow rate of 12m^3/hr corresponding to a filtration velocity of 12 m/hr.
- **Antiscalant**: Antiscalant (Flocon 135 dosing the 3 mg/l) is injected to prevent scaling of calcium sulphate, barium sulphate and metallic oxides.
- **Microfiltration**:RO skid is equipped with tow 5 µm cartridge filters of polypropylene with 10 m/h of velocity. [6]
- **Dechlorination**: Dechlorination with sodium metabisulfite can be performed upstream of the high pressure pump.

Moreover, the injection point is initially located upstream of the cartridge. [3-7]

- **Reverse Osmosis Unit**: The pre-treated water is pumped to the RO group by high pressure pump (19 bars). The RO group is composed of two stages. The first stage consists of two modules containing 12 RO TORAY spiral membranes (TM20-370). The second stage has one module containing 6 RO TORAYspiral membranes (TM20-370). The membrane is made of aromatic polyamide composite and each one has 34 m^2 /area. The average conversion rate is about 64% to 70%.
- **The post-treatment:** The post-treatment of permeate water to re-establish its calco-carbonic equilibrium includes the mixture of the permeate water with an equivalent quantity of the raw brackish water. This water is disinfected by calcium hypochlorite injection before put in reservoir of 200 m^3 capacity (Distributed water).

2.3. Pressure differentials

Pressures of the feed water of the first stage RO racks ranges from 11.2 to 12.16 bar. The second stage ranges from 10.2 to 11.04 bar. The differentials of the pressure for the first and second stages were 0.75 – 1.26 bar and 0.7-1.28 bar respectively (figures 2&3).The pressure difference is almost stable in both stages indicates absence of fouling the membranes.

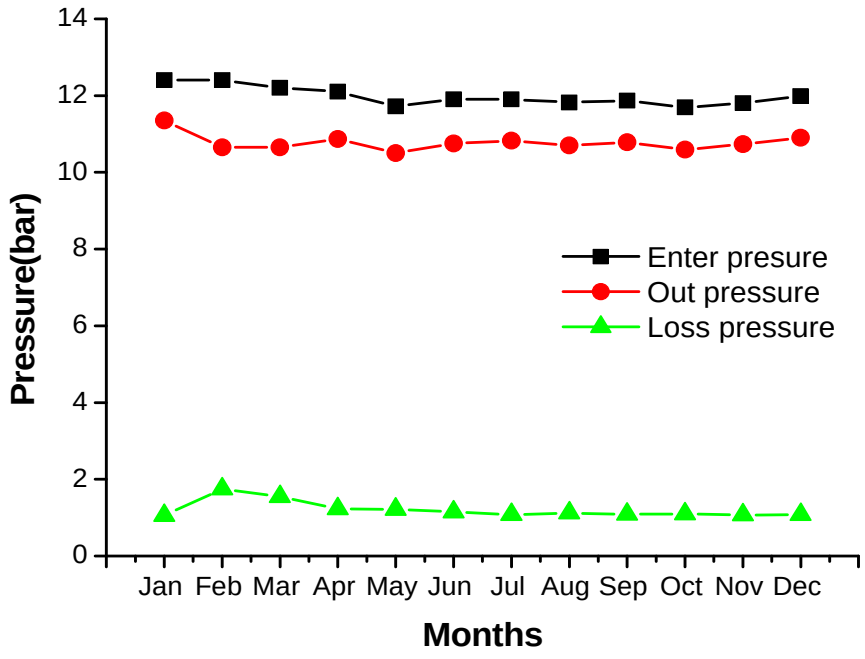


Figure 2: Variations the pressure of the first stage during one year

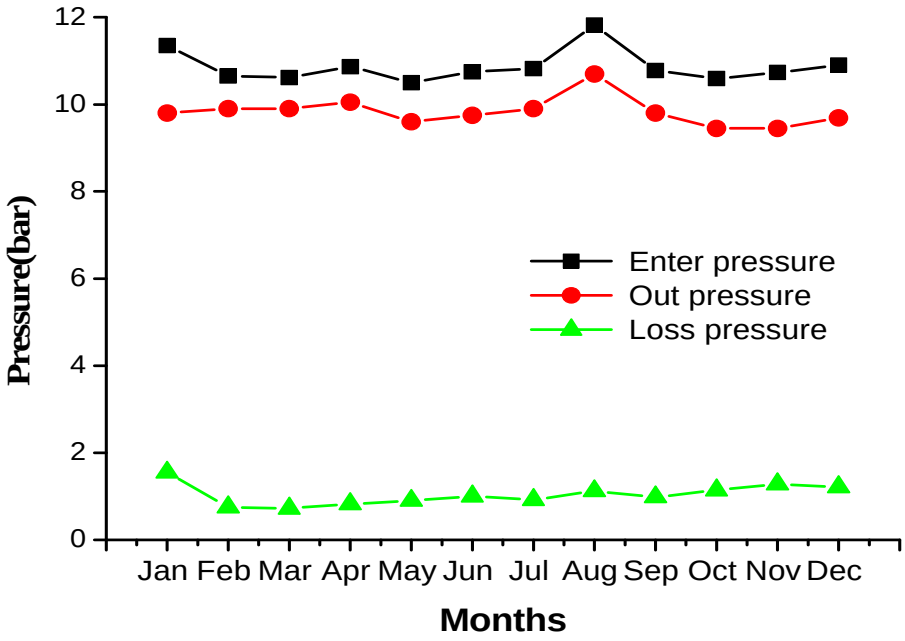


Figure 3: Variations the pressure of the second stage during one year

2.4. Cleaning of Membrane

The fouling of reverse osmosis elements is unavoidable with long-term operation. They can be fouled by biological matter, colloidal particles and mineral scale, element should be cleaned [8]. The protocol of membrane cleaning consisted of washing the membrane with several chemical solutions, it includes two steps:

-Alkaline solution, extremely effective against organic compounds.
-Acid solution, remove metal hydroxides, calcium carbonate, and other similar scales.
The consequence the frequency of cleaning the membrane, as often as twice per year.

RESULTS AND DISCUSSION

In this part, the results of the performances of the Tagounite plant was described, the plant operations were monitored continuously and the values of selected indicators were recorded every day in order to optimize the performances of the plant and to detected the trends and the potential problems for long-term. The analysis below covered an operational period of one year beginning from plant start-up.

3.1. Performances of Reverse Osmosis Plant

3.1.1. physico-chemical quality of the feed water pretreated and distributed water.

Figures. 4, 5, 6, 8, 9, 10and11, present the monthly variations of the physico-chemical parameters of the raw water, permeate water and distributed water during the one year of 2010.

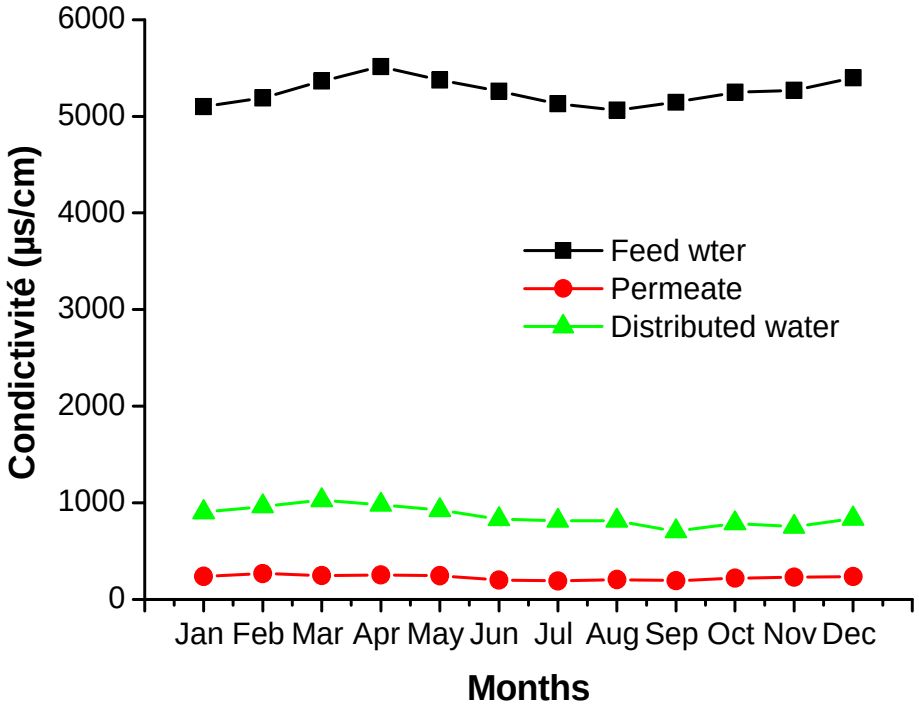


Figure 4: Variations of water conductivity during one year

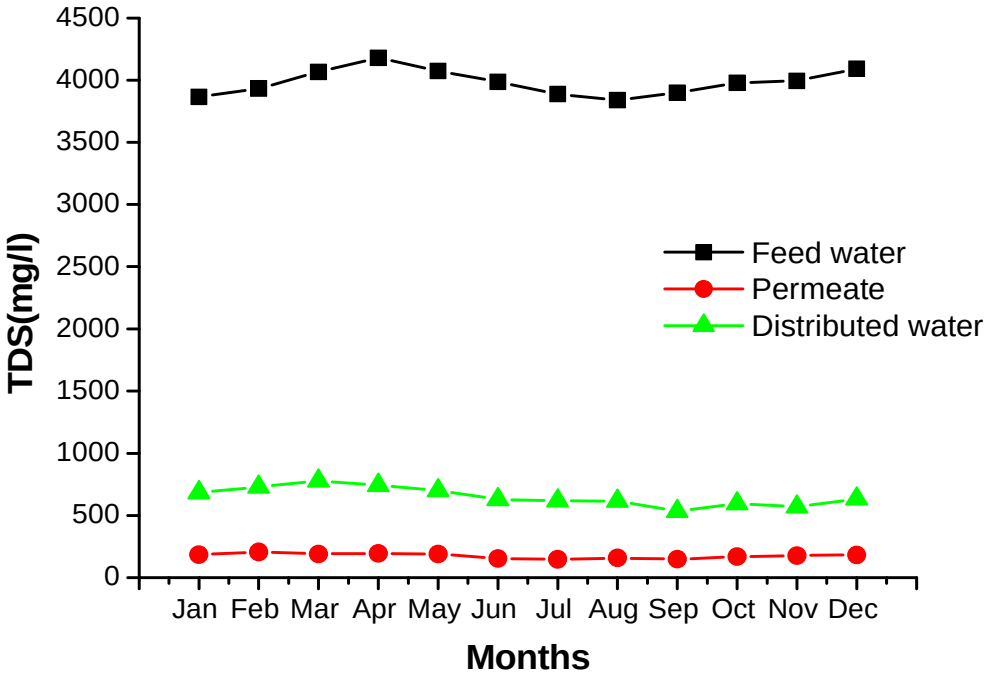


Figure 5: Variations of water TDS during one year

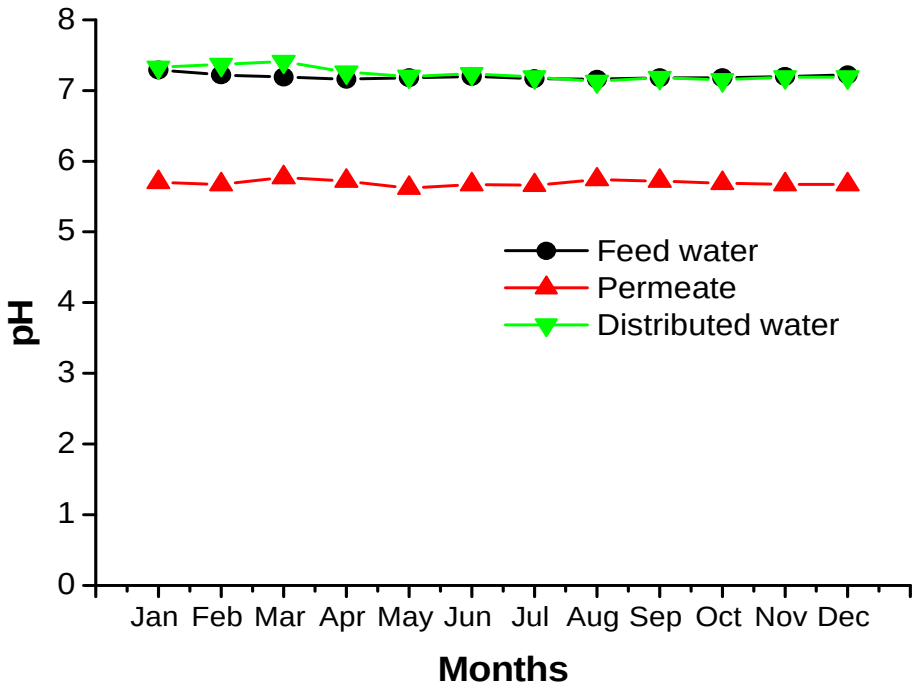


Figure 6: Variations of water PH during one year

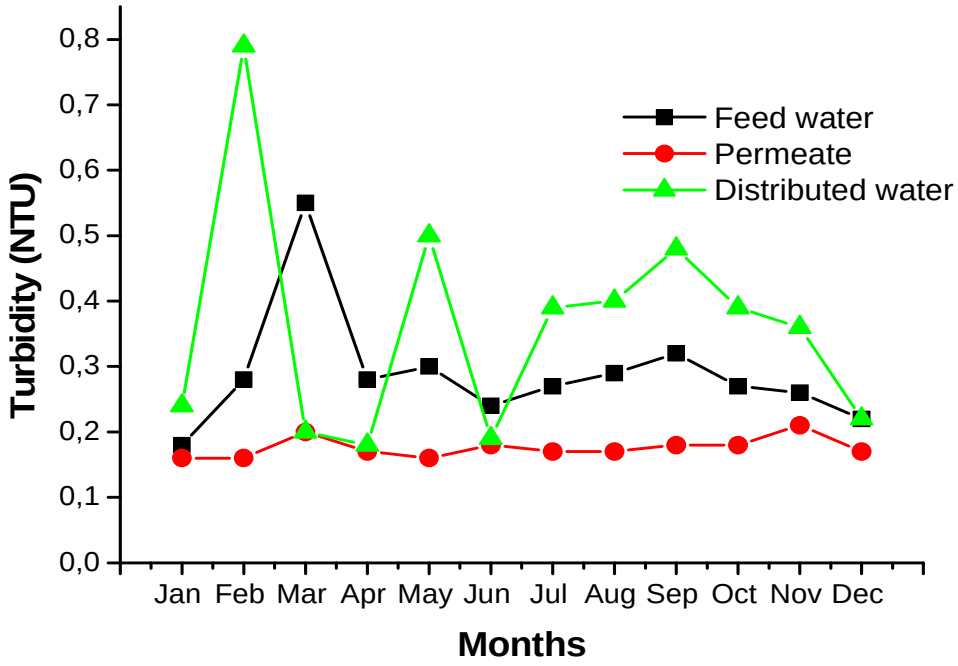


Figure 7: Variations of water turbidity during one year

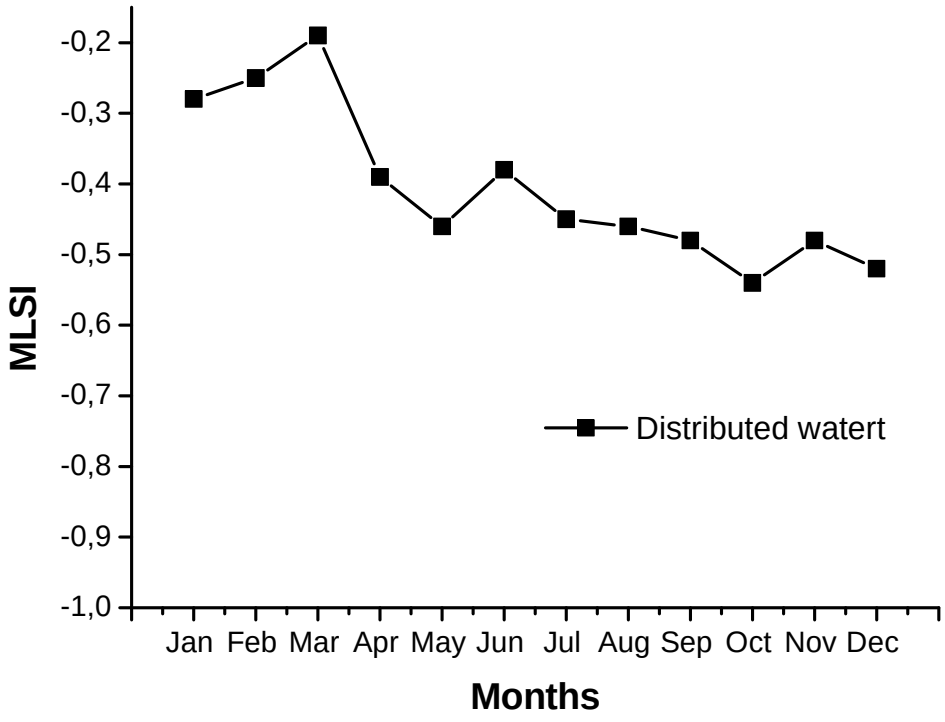


Figure 8: Variations of water langelier index the distributed water during one year

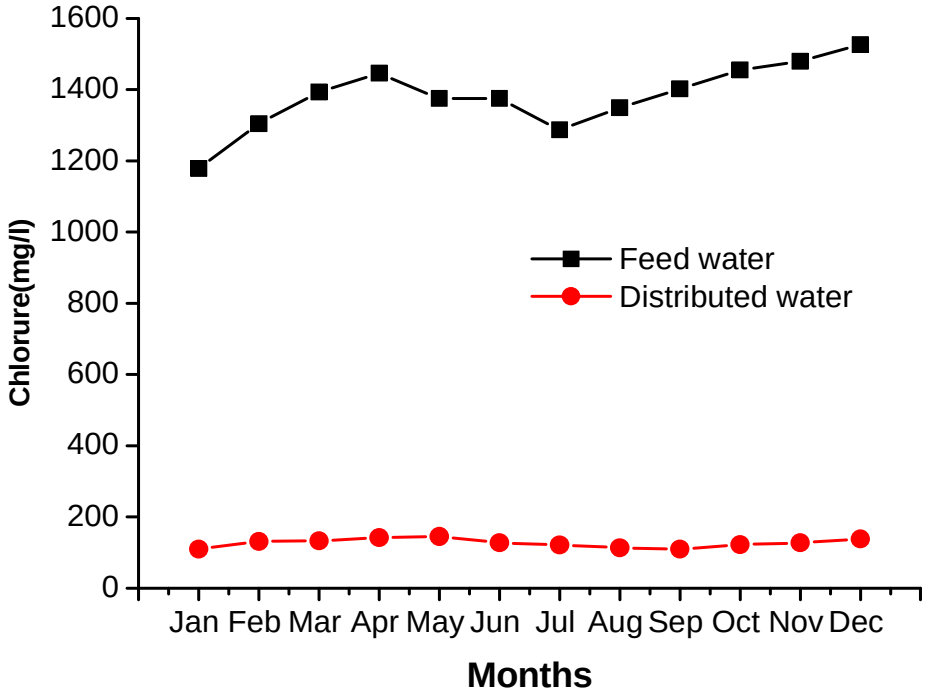


Figure 9: Variations of water Chlorure during one year

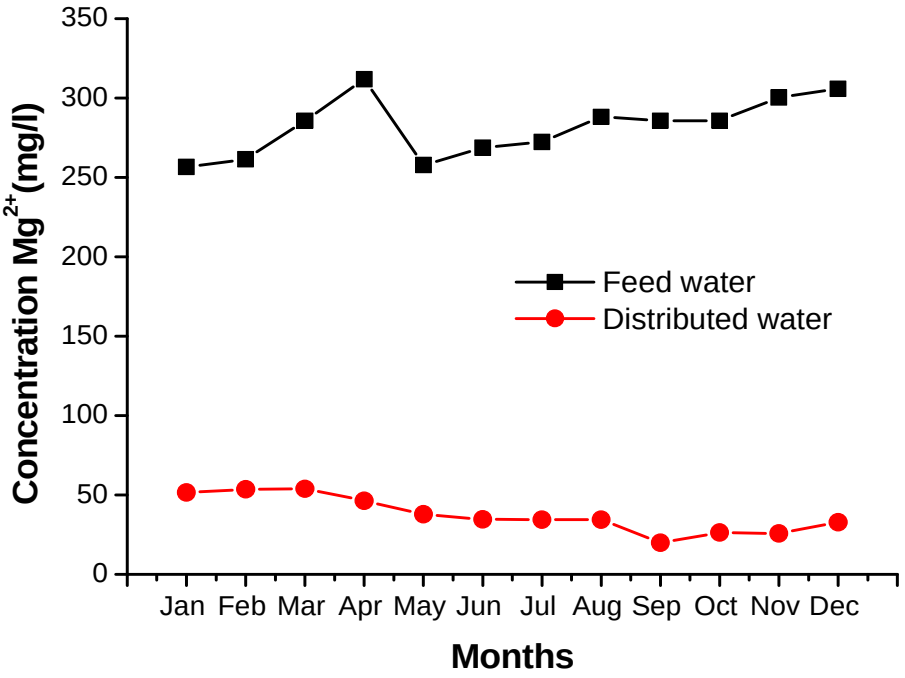


Figure 10: Variations of water concentration Mg^{2+} during one year

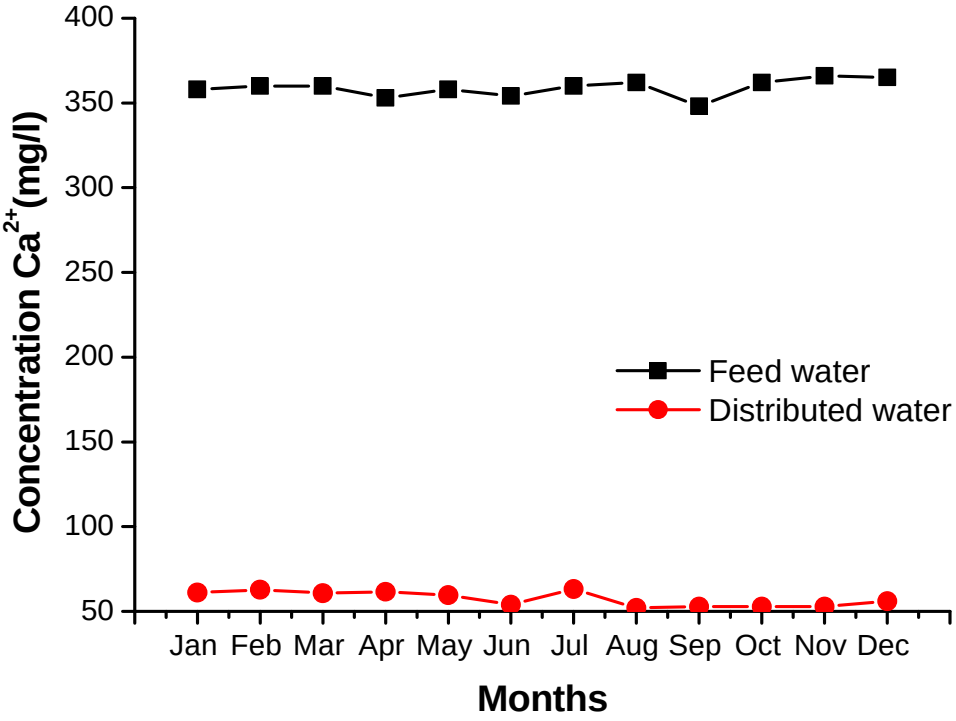


Figure 11: Variations of water concentration Ca^{2+} during one year

After demineralization by reverse osmosis, the overall rejection rate is high resulting in a conductivity of the treated water of the variations of 259-424 µS/ cm and TDS 196-321 mg/l(figure.4&5). The demineralization by reverse osmosis has also an effect on the change in pH which takes values 5.66 to 5.67. (Figure.6).

The water treated by reverse osmosis unit is mineralized with fresh water of the well to make a water treated its calco-carbonic equilibrium.

As showed Figure .7, the turbidity of the permeate and distributed water has the rate 0.13 – 0.40 NTU. This value respects the Moroccan standards of drinking water. The silt density index (SDI) of pretreated water has a value < 1, indicate the good preatretement of the raw water and prevent the fouling of membrane.

Also, the MLSLI negative of the variations of -0.4 to -0.79 indicates that the distributed water is slightly aggressive (Figure. 8).

The results show that the quality of the distributed water after demineralization by reverse osmosis is satisfactory in term of the physic-chemical parameters such as the conductivity, pH, turbidity, SDI, Index langelier, cholorure, calcium and magnesium level (shown figure 4, 5, 6, 7,8,9,10 and 11). Also the distributed water respects the Moroccan standards of drinking water.

3.1.2. Microbiological quality of the feed water pretreated and distributed water.
Figures 12, 13, 14 and 15, present the monthly variations of the microbiological feed water, pretreated water and distributed water.

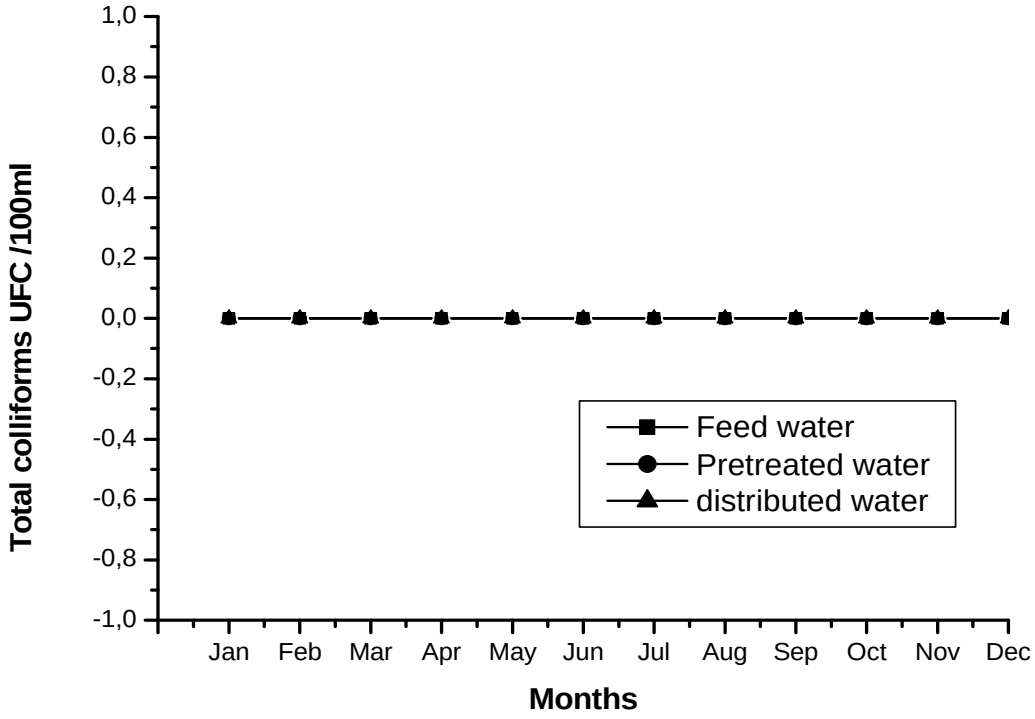


Figure 12: Variations of water the total coliforms during one year

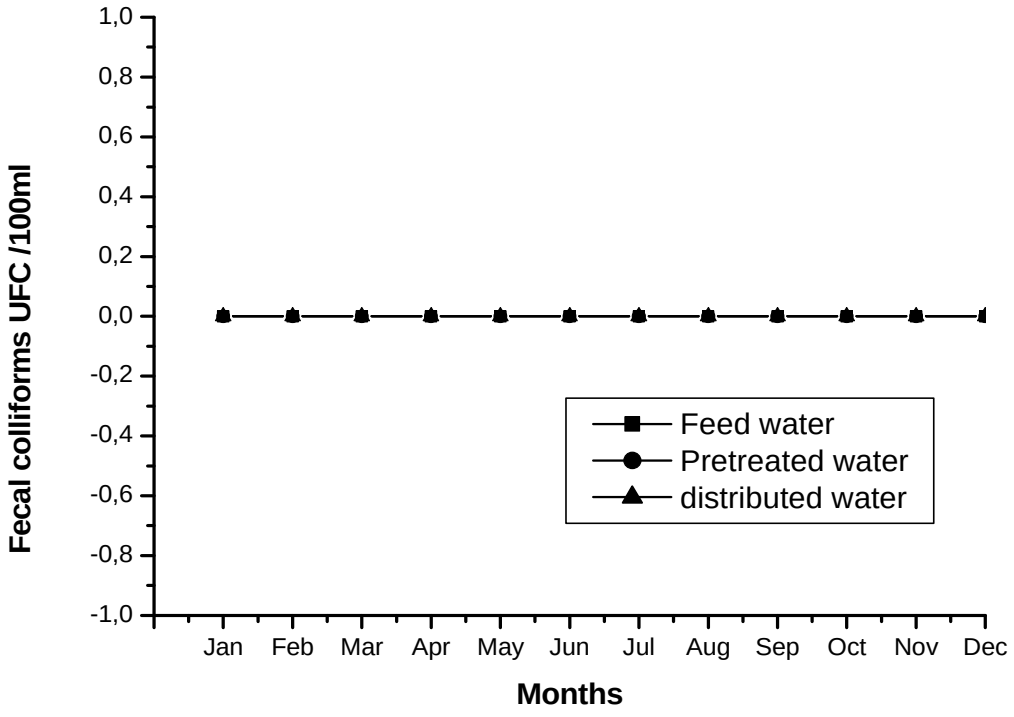


Figure 13: Variations of water the fecal coliforms during one year

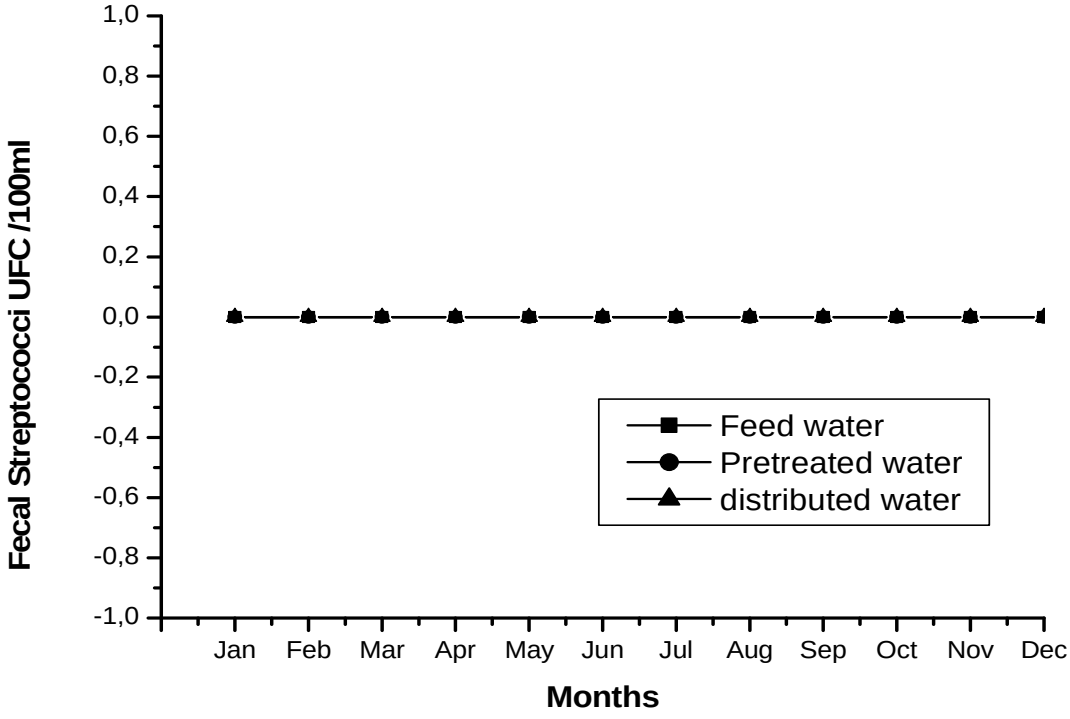


Figure 14: Variations of water the fecal streptococci during one year

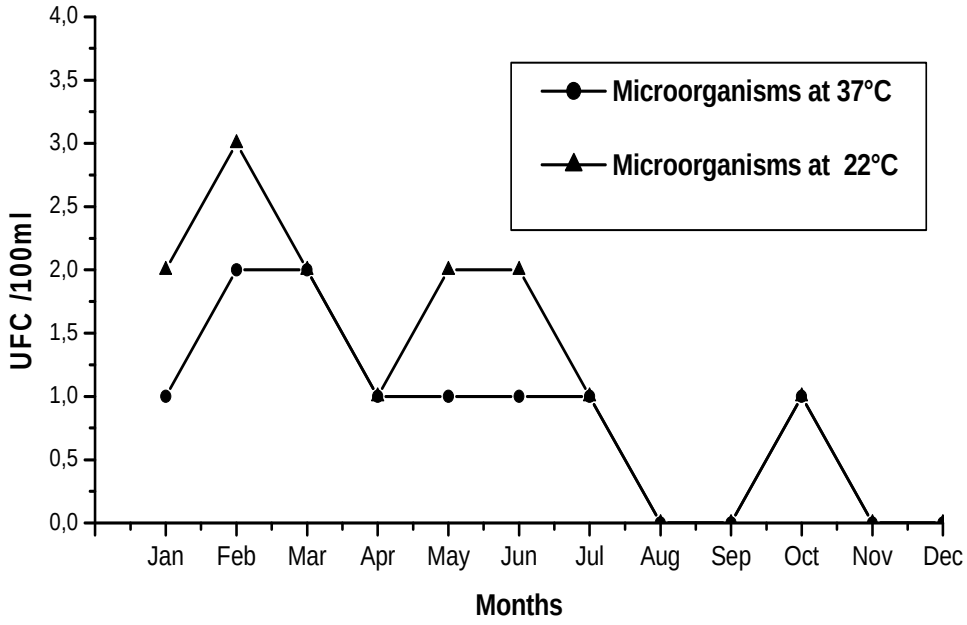


Figure 15: Variations of water the microorganisms the distributed water during one year

The analysis of the results bacteriological of distributed water shows in figure 12,13,14 and 15.The average load in total coliforms is 0 UFC / 100 ml, 0 UFC / 100 ml of fecal coliforms, 0 UFC / 100ml of fecal streptococci and 0-3 UFC/100ml of microorganisms (at 22°C and 37°c). On the one hand, this result is consistent with the Moroccan standards of drinking water for human consumption and the distributed water has good qualities bacteriological. On the other hand, it confirms that there is a good disinfection; a pathogen destruction.

CONCLUSION

The water produced by the desalination plant of Tagounite has a satisfactory quality, and respects the Moroccan drinking water standards. Also, the plant displays a better performances and the satisfactory reproducibility. This result shows clearly the interest of the implementation of this desalination plant to solve the problem of the shortage of drinking water for Tagounite.

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