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PERFORMANCES OF REMINERALIZATION POST FOR REVERSE OSMOSIS (RO)-DESALTED WATER

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ABSTRACT

From the launching of the Laâyoune desalination plant, the post-treatment process was based on caustic soda for the remineralization of the produced water. Consequently, two problems were encountered during the plant operation: both the aggressivity and the corrosivity of the produced water cause the gradual damage of the water transport canalizations. To reduce these negatives impacts, the caustic soda was substituted by the lime, using a saturator.

This study was conducted to examine the performances of lime $Ca(OH_2)$ on the stabilities of the distributed water and the pipeline materials. The results show that the distributed water presents a satisfactory quality according to the Moroccan guidelines of drinking water with an excellent reproducibility. The analysis and operation of the performances of the saturator by lime has highlighted the recommendations to be followed in case of malfunction of the process.

Key words: Reverse osmosis, Post-treatement, Remineralization, Aggressivity, Corrosivity, Saturator by lime, Performances, Recommendation.

INTRODUCTION

The permeate quality of seawater reverse osmosis (SWRO) plants is suitable neither for drinking water nor for irrigation purposes[1,2]. Thus, remineralization process is required to convert the product water from desalination process units into potable water for civil consumption[3]. The main processes for the remineralization of the desalinated

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water are as follows[3-7]:

- Limestone dissolution by carbon dioxide,
- Application of sodium bicarbonate and calcium sulphate,
- Application of hydrated lime and sodium carbonate,
- Application of online micronized lime,
- Application of carbon dioxide and excess hydrated lime.

The remineralization process adopted for the Laâyoune plant from the beginning of its operation was based on caustic soda (for pH adjustment), to reduce the aggressivity and corrosivity of the produced water. The main problem encountered during the operation of the plant was the aggressivity correction facility of the produced water, which was inefficient because it failed to enable this water to be brought to its calcocarbonic equilibrium. In fact, it was noticed that the produced water, due to its corrosivity, attacks the metallic equipment; and because of its aggressivity, it also attacks the transport canalization made of concrete. This was confirmed by a pH increase in the produced water, which reached 9 in one of the distribution tanks located at 9 Km away from the plant while it was 8 at the outlet of the plant.

In order to solve this problem, the caustic soda was substituted by lime saturator. This process consists in adding milk to acidify desalted water containing carbon dioxide, as shown by the following reaction:

$$2\ CO_2 + Ca\ (OH)_2 \longleftrightarrow Ca^{2+} + 2\ HCO_3^- \qquad \ldots(1)$$

This method presents fewer disadvantages than the other methods. It enriches the water with both TH and alkalinity (at a 1 : 1 ratio, in equivalent units). The most frequent challenge with the operation of such remineralization systems is maintaining low turbidity in the finished drinking water because lime can cause a turbidity increase, often exceeding 5 NTU[4,8-11]. Moreover, the use of hydrated lime slurry is relatively complex from the engineering point of view[4,12-14], especially if the permeate is warm, which reduces the solubility of lime[8].

However, this method is still widely applied[13]. Today, the most commonly used post-treatment system in desalination plants worldwide is the sequential addition of

lime and carbon dioxide as in Australia, the U. S. A, the Middle East, Spain, and North Africa[11].

In previous paper, Elazhar et al.[15], studied the optimisation of the functioning conditions of the saturator by lime such as the flow and the concentration of the lime. The cost of cubic meter of the post-treatment part was evaluated also. Thus, the main aims of this study were, on the one hand to demonstrate the performances of the saturator by lime in the reduction of the aggressivity and the corrosivity of the permeate seawater reverse osmosis plant, and to describe, the recommendations to be followed in case of malfunction of the process to the other.

EXPERIMENTAL

Methods and materials

Laâyoune desalination plant

The Laâyoune seawater reverse osmosis plant started its operation in 1995, with a capacity of 7000 m^3/d, and by 2005, its capacity has been increased to 13,000 m^3/d. Today the capacity of plant riches to 26.000 m^3 /d. Fig. 1 gives the different steps of Laâyoune desalination plant.

Quality of the permeate water to be remineralized

Table 1 presents the main characteristics of the permeated water and the required characteristics, after remineralization, following the Moroccan standards for drinking water.

Table 1: Characteristics of the permeated water and Moroccan standard for drinking water

Parameters	Permeate seawater	Moroccan standards for drinking water
pH	5.3	6.5-8.5
Turbidity	0.17 NTU	5 NTU
TAC	2 mg/L	200 mg/L
Ca^{2+}	3 mg/L	500 mg/L
Langelier Index (MLSI)	- 0.94	$-0.2 < MLSI < 0.2$

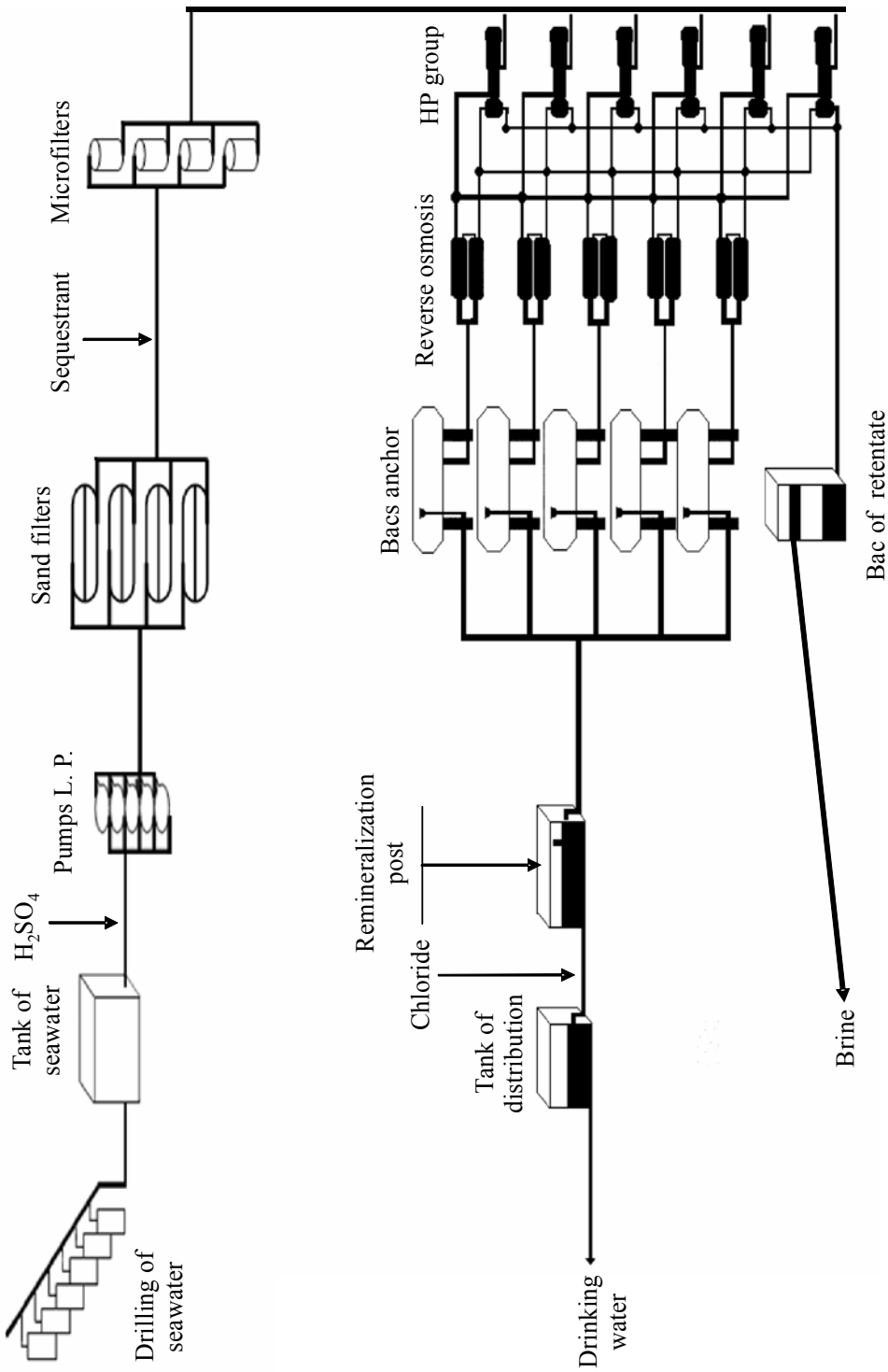

Fig. 1: Laâyoune desalination plant

Remineralization post

Fig. 2 shows the remineralization post.

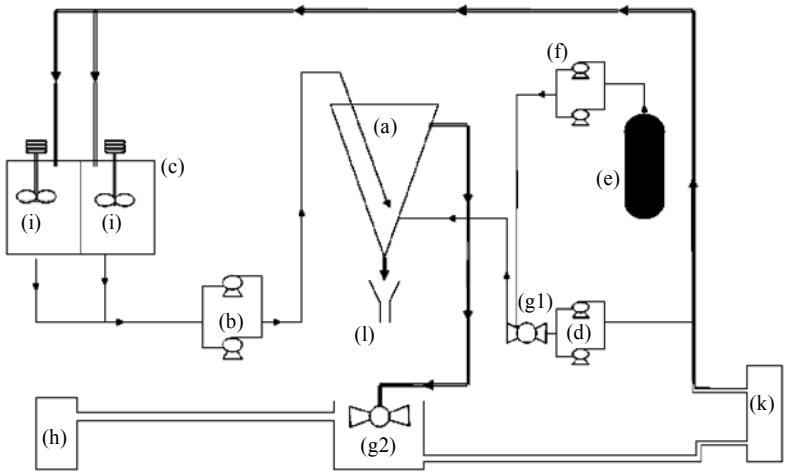

Fig. 2: Remineralization post

(a) Saturator, (b) Milk injection pumps, (c) Lime milk preparation tank, (i) Stirrer (d) Injection pump of permeated water, (k) Permeated water pipe, (e) Silicate storage tank, (f) Silicates injection pumps, (g1, g2) Static mixer, (l) Purge, (h) Distribution of the remineralized water. The lime milk is prepared by mixing bags of lime with the permeated water. The preparation is carried out manually in tank (c). The cylindro-conical saturator receives firstly lime milk from tank (c) and secondly a solution of silicate to reduce turbidity from tank (e). In fact, the preparation of lime water with osmosis water leads to a quick precipitation of carbonates originating from atmospheric or dissolved CO_2.

The silicates solution is prepared in tank (e) by diluting with permeated water, commercial solution of silicates at a concentration of 1.350 g/m³. The injection of silicate decreases the turbidity of lime water from 50-100 NTU to 10-12 NTU, which considerably reduces the probability of finding undesirable molecules in the remineralized water. Table 2 gives the operational characteristics of the lime saturator post[15].

Table 2: Operational characteristics of the lime saturator post

Operational characteristics	
Permeate flow	550 m^3/h
Concentration of lime	106 g/L
Flow of lime	360 L/h
Flow of silicates	0.58 L/h
Flow of acide pretratement (H_2SO_4)	24 L/h

RESULTS AND DISCUSSION

Performances of the saturator by lime

Figs. 3, 4 and 5 give respectively the variation of the pH and content of TAC and THCa versus time at three points: output of reverse osmosis module (k), static mixer (g2) and tank of distribution (h).

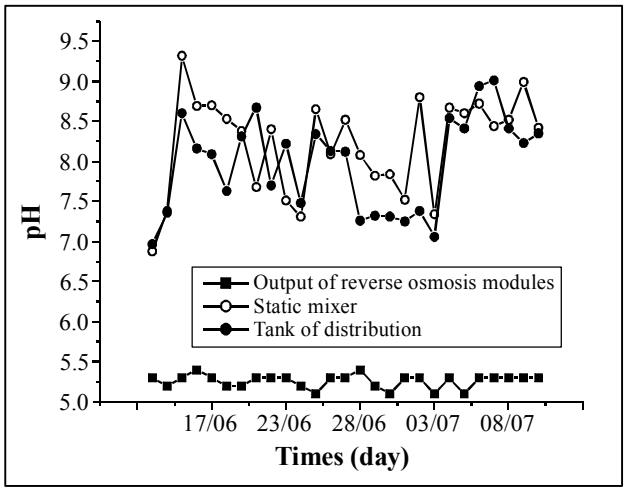

Fig. 3: Variation of pH versus time

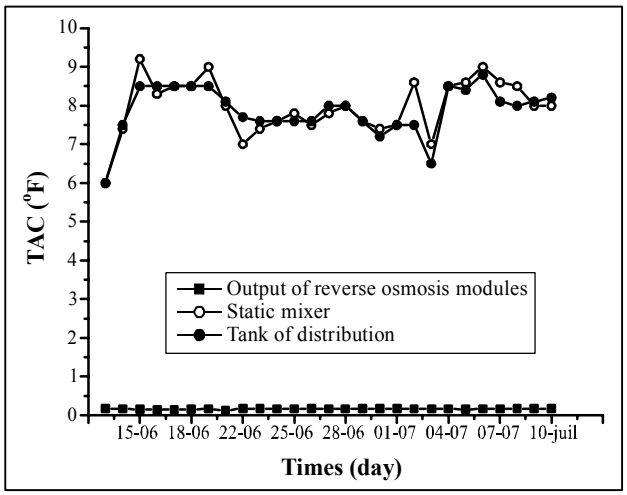

Fig. 4: Variation of TAC versus time

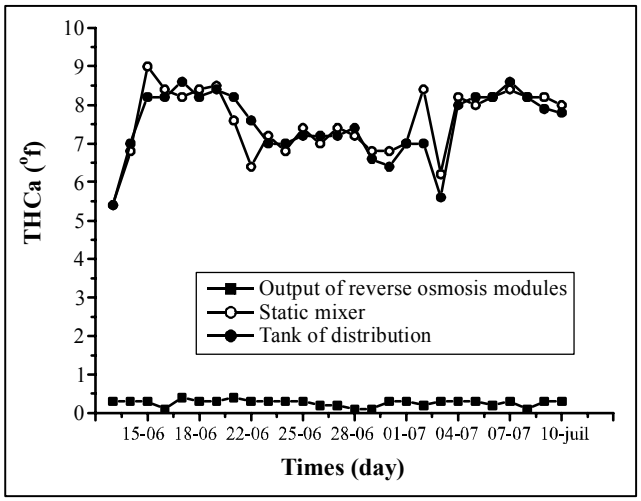

Fig. 5: Variation of THCA versus time

Figs. 6 to 8 show respectively the variations of conductivity, turbidity and Langelier index at the same points.

To confirm the effectiveness of the new system of remineralization, the following parameters were determined before and after remineralization: CO_2 activity, and the value of the supersaturation (Ω). Figs. 9 and 10 give the variation of these parameters versus time.

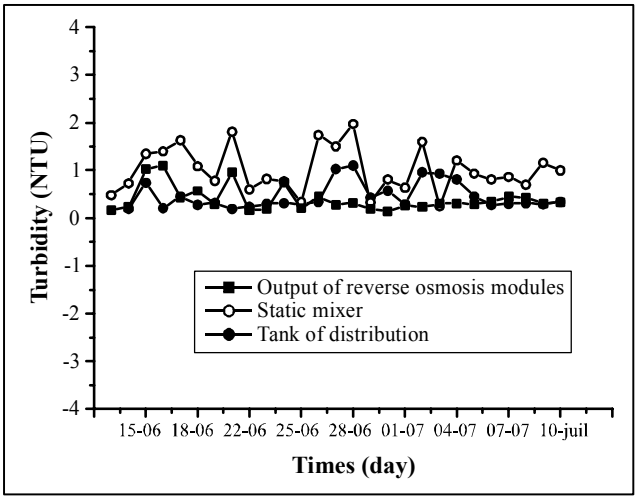

Fig. 6: Variation of turbidity versus time

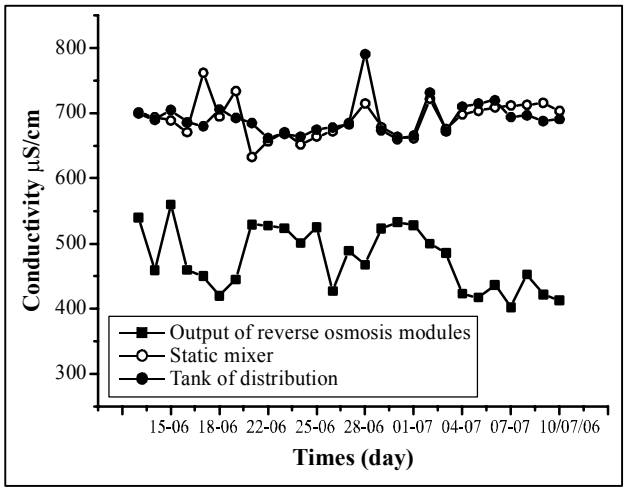

Fig. 7: Variation of conductivity versus time

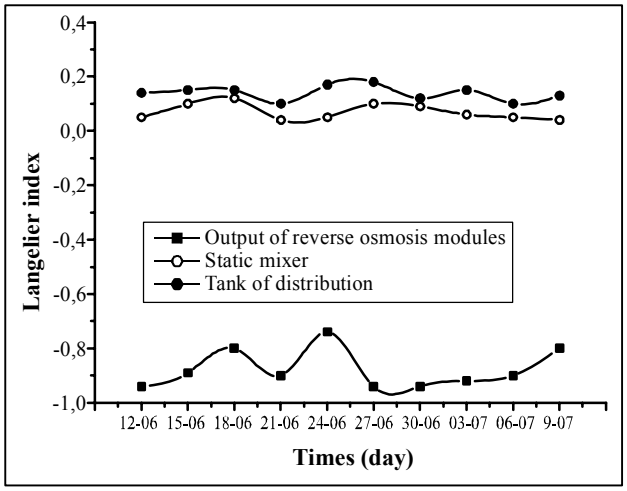

Fig. 8: Variation of Langelier index versus time

The analysis of the results shows that:

- A significant improvement in the quality of the distributed water compared to the output of reverse osmosis modules.
- The values of pH, TAC, THCA and conductivity increased significantly, and meets the overall objective of this study, which was to achieve water suitable for Moroccan guidelines of drinking water.

- Despite the slight increase in turbidity in the water of distribution compared to the water at the outlet of the reverse osmosis modules, it remains within acceptable standards for drinking water
- The quality of water in the static mixer and the bac of distribution are substantially the same.
- The several parameters in relation with the aggressiveness (conductivity, activity of CO_2, supersaturation (Ω), and the monohydrated form of the Langelier Scaling Index (MLSI)) were ameliorated confirming the reduction of the risk of the corrosion of the produced water and the usefulness of the operation of the remineralization.

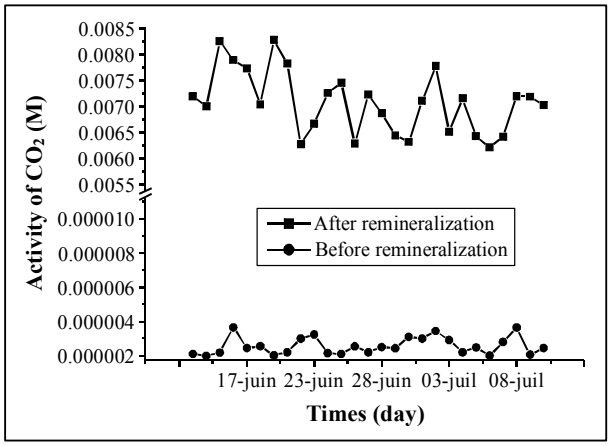

Fig. 9: Variation of activity of CO_2 versus time

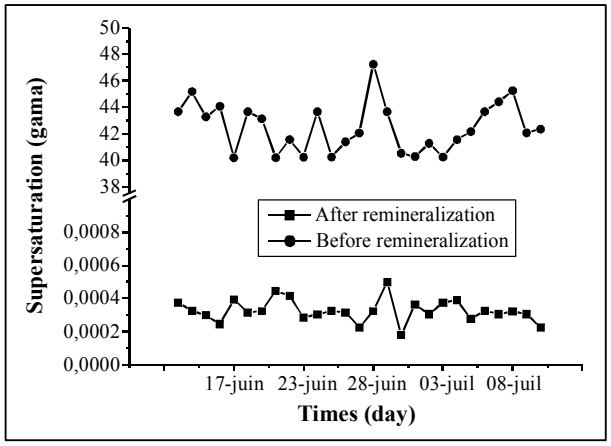

Fig. 10: Variation of supersaturation (Ω) versus time

Recommendations

The monitoring and the analysis of the parameters of the remineralization process by lime have highlighted the following recommendations:

↳ Si **8 < pH < 8,5, TAC = 8 (°F), THCa = 8 (°F), NTU > 1** :

- Carry out the manual purge of the saturator or increase the flow of silicates in order to reduce turbidity.

↳ Si **8 < pH < 8,5, TAC = 8 (°F), THCa = 8 (°F), NTU < 0.2 :**

- Decrease the flow of silicates as the turbidity is very low.

↳ Si **pH < 8,00, TAC < 8, THCa = 8 (°F), 0.2 < NTU < 1:**

- Increasing the addition of the acid in the pretreatment part for increasing the content of free CO_2 in the permeate.

↳ Si **pH > 8,5, TAC < 8 (°F), THCa =8 (°F), 0.2<NTU<1:**

- Reduce the alkalinity by adding acid (H_2SO_4) in the preprocessing phase.

↳ Si **pH < 8,00, TAC < 8 (°F), THCa < 8 (°F), 0.2<NTU<1:**

- Check the flow of the milk injection pump,
- Rise slightly the treatment period.
- Verify the pipes of milk lime (washing of the pipes).
- Add the lime in the tank of preparation.

↳ Si **pH > 8,50, TAC > 8 (°F), THCa >8 (°F), 0.2<NTU<1:**

- Decrease the flow of the milk injection pumps.
- Increase the flow of the injection pump of permeated water.
- Reduce the number of bags of lime in the tank of preparation.

CONCLUSION

This study confirms the good performances of saturator by lime in reduction of the aggressivity and the corrosivity of permeate seawater reverse osmosis. The quality of the

remineralized water is satisfactory and meets the standards required by ONEP for the distribution of drinking water. Despite the high cost of the remineralization process with the saturator by lime, the risks of corrosivity and agressivity are lower with the lime.

The analysis and operation of the performances of saturator by lime have highlighted the recommendations to be followed in case of malfunction of the process. The variation of the functioning and analysis parameters of the saturator is mainly due to technical problems related to the purity of the lime used, clogging of the routing pipes of the milk of lime and the blocking of the dosing pump.

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