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Coupling softening — ultrafiltration like pretreatment of sea water case study of the Corso plant desalination (Algiers)

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Abstract

The demand of fresh water is increasing twice as fast as population growth, while the natural resources remain invariable or in reduction. Otherwise, the needs of development make that the demand will be superior to resources. To satisfy these last, new techniques of drinking water production implementation by using the desalination of sea water by reverse osmosis. We have the results relating to the pretreatment of the sea water plant desalination by reverse osmosis located in (Corso) the east of Algiers at the Mediterranean sea side. With an aim of increasing the efficiency and the lifespan of reverse osmosis plant in order to avoid or to minimize, the scaling and the membranes fouling, the water pretreatment sea is necessary. The sea characteristics water are: total hardness (390°F), conductivity (55,000 μs/cm), turbidity (8.40 NTU). Like technique of pretreatment, we chose the water softening of sea by lime, the resin and ultrafiltration, and finally coupling ions exchange — ultrafiltration and coupling precipitation by lime-ultrafiltration. Three resins amberlite CG 50, CG 400, IR 120 were used. The ultrafitration tests have been made on tubular mineral membrane CARBOSEP M2 (15 kg/mol). The coupling treatment of the filtrate by ions exchange (amberlite IR 120) to ultrafiltration gave the best result with 98% of turbidity reduction, a final value of 0.13 NTU. An improvement of the limit permeate flux was obtained, where the value passed from 30.6 L/h m^2 (ultrafiltration alone) to a value of 47.5 L/h m^2 for a concentration of 360 mg/L of the resin amberlite IR 120 with an increase of 35%.

Keywords: Reverse osmosis; Ultrafiltration; Pretreatment; Seawater

1. Introduction

Algeria, from its development program and its vast arid and semi arid, is directly confronted with the problems of the fresh water availability, at the same time for consumption of drinking water, agriculture, industry. The water research of good quality proves to be essential for the survival of the alive beings on ground. To face this announced water shortage, new techniques of drinking water production very powerful thus could be applied to satisfy the needs for the

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increasing population. One of the promising techniques for certain countries is the sea water desalination. To preserve the efficiency and the lifespan of reverse osmosis installation, a water pretreatment is necessary. This last will make it possible to avoid or minimize the scaling and the membranes fouling. Former studies were undertaken. Zhang et al. [1] tested the potential of ultrafiltration prior to reverse osmosis for high turbidity seawater. Brehant et al. [2] allowed the reduction of the membranes fouling of reverse osmosis by using ultrafiltration with SDI values very weak.Wolf et al. [3] showed that ultrafiltration unlike conventional pre-treatment technologies, provides a physical barrier to particulate and colloidal material and ensures that RO plants can operate on a continuous basis, at high and stable fluxes, at higher recovery rates. Halpern et al. [4] showed that the use of ultrafitration membranes is now being considered as a viable solution for pretreatment to seawater reverse osmosis plants. Ultrafitration membranes can provide product water with consistently low turbidity, regardless of seawater quality. Teng et al. [5] used the various methods of pretreatment by using ultrafiltration and microfiltration. Test results showed that membrane pretreatment consistently reduced filtrate of good quality.

This work aims to examine the possibility of finding a pretreatment adequate with sea water of Corso desalination plant by the coupling softening ultrafiltration. for this purpose, we considered the elimination of the water hardness by ions exchange and decarbonatation to lime by determining the optimum conditions for softening by precipitation. Ultrafiltration test on raw water were done and proceed to the coupling softening-ultrafiltration.

2. Experimental conditions

2.1. Description of the station

The Corso desalination plant of sea water located at 35 km of the Algiers east localised along the coastal tape of the Mediterranean sea with total capacity of 5000 m^3/J with a conversion rate equal to 40%. The current pretreatment comprises a coagulation, decantation followed by filtration.

2.2. Characteristics of raw water

The following table gives the principal characteristics of the Corso plant sea water followed bacteriological analyses. The physico-chemical analyses make it possible to control the water composition and its quality in reference to the potability standards.

We notice that the total hardness is very high 390°F. It is a significant step for the systems design of pretreatment and the reverse osmosis system, in order to determine the type and the pretreatment size.

The bacteriological analyses indicate the absence of indicator germs of fecal pollution, one

Table 1
Characteristics of raw water

Parameters	Mean value	Algerian potability standards
Turbidity, NTU	8.40	5
Total hardness, °F	390	50
TAC, °F	11.66	35
TDS, mg/L	58,000	500
Ca^{2+}, mg/L	449	200
Mg^{2+}, mg/L	1387	150
Na^+, mg/L	12,179	250
K^+, mg/L	418	12
Cl^-, mg/L	21,555	600
SO_4^{2-}, mg/L	3200	250
HCO_3^-, mg/L	158.6	–
NO_3^-, mg/L	0	50
Conductivity, μs/cm	55,000	–
SiO_2, mg/L	0	–
Fe^{2+}, mg/L	<0.01	0.2
pH	8.4	6.5–8.5
Temperature, °C	18–22	30

Table 2
Bacteriological analyses

Microbiological parameter	Value	Algerian potability standards
Fecal coliformes	Absence	0 CFU/100 mL
Total coliformes	Absence	0 CFU/100 mL
Clostidium sulfito-reducing	Absence	0 CFU/100 mL
Streptocoques fecal	Absence	0 CFU/100 mL
Escherichia coli	Absence	0 CFU/100 mL

concludes that the sea water is very good bacteriological quality.

2.3. Experimental procedures

Step 1: Essays of jar test — Determination of the optimum conditions for decarbonatation by lime, to introduce increasing lime amounts between 10 and 900 mg/L into a series of 10 flasks, one carries out tests of gravel bank test. Initially, the mixture is agitated during 2 min at a speed of 250 tr/min, then to reduce speed to 60 tr/min during 15 min. After setting (45 min), the supernatant is taken for analyses.

Step 2: Essays of jar test — Determination of the optimum conditions for decarbonatation by lime-caustic soda. To introduce increasing lime amounts between 80 and 600 mg/L by adding soda between 90 and 400 mg/L into a series of 5 flasks.

Step 3: Study of the conditions optimal for softening by coupling ions lime-ultrafiltration. To introduce amounts of the lime of $C = 600$ mg/L into a series of 10 flasks of one liter solution sea then on the gravel bank test, the supernatant is taken in the well agitated feed tank, while following the evolution of the permeate flux, turbidity according to time.

Step 4: Study of the conditions optimal for softening by coupling ions exchange-ultrafiltration.

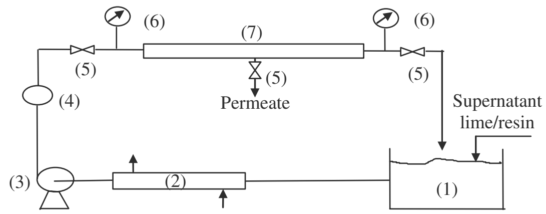


Fig. 1. The experimental set up.

The operating conditions are identical at step 3 except that the supernatant of the resin is put in the feed tank.

The analyses consist in evaluating the following parameters: turbidity; total hardness TH; calcium hardness Ca^{2+}; magnesium hardness Mg^{2+}.

2.4. Experimental set up

This consists of feed tank (1) where the supernatant is added. A heat exchanger (2), a centrifugal pump (3), a flow meter (4), control valves (5), manometers (6), a mineral membrane ultrafiltration tubular (7) CARBOSEP M2 (15 kg/mol) (Fig. 1) in dynamic mode with a transmembrane pressure $\Delta P = 1$ bar and a cross flow velocity $U = 3$ m/s.

2.5. Reagents

Three resins amberlite CG 50, CG 400, IR 120, lime and the caustic soda are used.

3. Results and discussion

3.1. Softening

3.1.1. Determination of the optimum conditions for decarbonatation by lime

Fig. 2 shows the variation of total hardness according to the lime concentration, in order to determine the optimal amount of lime.

As the concentration of lime increases, we observe a decrease total hardness (TH), in consequence of the hydrogenocarbonates (HCO_3^-)

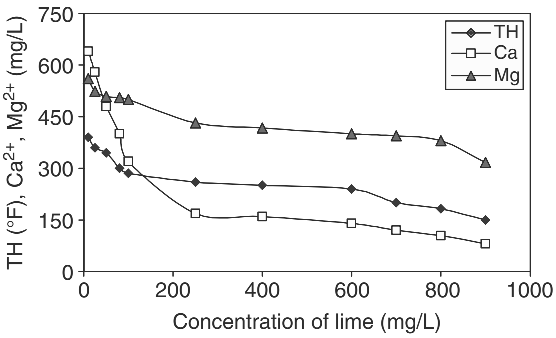


Fig. 2. Evolution of the parameters: TH, Ca^{2+}, Mg^{2+} in function concentration of lime.

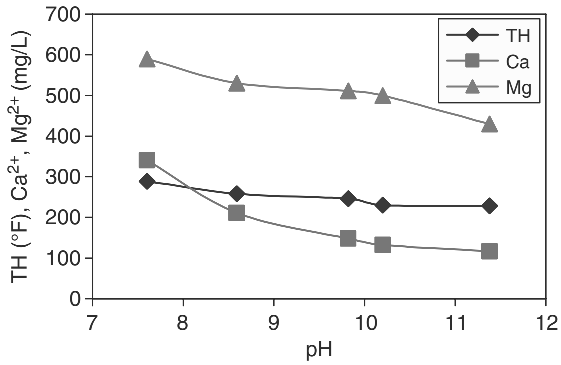


Fig. 3. Evolution of parameters: TH, Ca^{2+}, Mg^{2+} as function of pH.

transformation which is converted into ions carbonates (CO_3^{2-}) and which can then react with the Ca^{2+} ions and Mg^{2+} to form a precipitate according to following reactions:

$$Ca(OH)_2 + CO_2 \rightarrow Ca(HCO_3)_2 \quad (1)$$

$$Ca(OH)_2 + Ca(HCO_3)_2 \rightarrow 2CaCO_3 + 2H_2O \quad (2)$$

$$2Ca(OH)_2 + Mg(HCO_3)_2 \rightarrow 2CaCO_3 + Mg(OH)_2 + 2H_2O \quad (3)$$

Thus hardness is decreased. It appears that the lime optimal concentration giving the best reduction is equal to C = 600 mg/L, it allows a reduction 38% with a value of 240°F. A significant reduction of turbidity with a final value 2.08 NTU.

3.1.2. Determination of the optimum conditions for decarbonatation by lime caustic soda

The elimination of the ions calcium and magnesium by precipitation by caustic soda is an alternative of the treatment process by lime according to:

$$Ca(HCO_3)_2 + 2NaOH \rightarrow CaCO_3 + Na_2CO_3 + 2H_2O \quad (4)$$

The Table 3 gives the experiments results:

The pH value is essential with the good conduit of softening by precipitation. The softening pH depends on water to treat. For a better decarbonatation with lime the optimal pH is equal to 11.38. The Fig. 3 shows the evolution of TH, Ca^{2+}, Mg^{2+} as function of pH.

Table 3
Optimisation of the pH for a better decarbonatation with lime-caustic soda. TA = 6.66°F, TAC = 11.66°F

Parameters	Concentration (mg/L)				
	$C_{Ca(OH)_2}$ = 80	100	250	400	600
	C_{NaOH} = 90	100	200	300	400
	pH = 7.6	pH = 8.59	pH = 9.82	pH = 10.2	pH = 11.38
TH (°F)	289	258.1	246.3	230.4	228.57
Ca^{2+} (mg/L)	340	210.9	148.2	131.86	116
Mg^{2+} (mg/L)	590	530	510.6	500	430

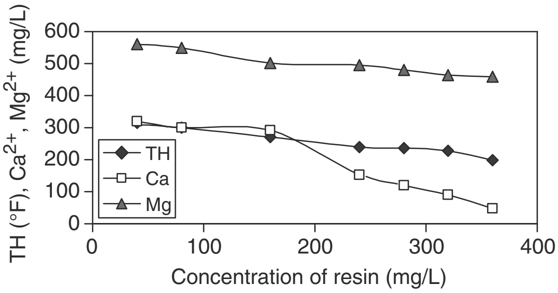


Fig. 4. Evolution of parameters: TH, Ca^{2+}, Mg^{2+} in function concentration of the resin.

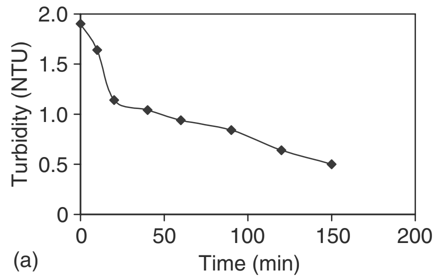
3.1.3. Determination of the optimum conditions for softening by exchange ions

The results represented by Fig. 4 reveal that the resin compared gives very good elimination to lime and that the optimal concentration of the resin is $C = 360$ mg/L.

A reduction of total hardness is 49% in jar test by the resin addition IR120, a final value of 198°F. A significant turbidity reduction: 90% jar-test, by the addition of the resin gives a residual value of 0.84 NTU. We notice that, only that this method does not allow the water treatment of sea whose salinity is too high.

3.2. Ultrafiltration test

The turbidity decreases according to the ultrafiltration time (Fig. 5a) what corresponds to a retention of the colloidal particles. The turbidity varies from 1.9 NTU with 0.5 NTU, a reduction of 73, 68% is obtained, which proves the efficiency of the treatment by ultrafiltration. The evolution of the permeate flux according to the ultrafiltration time of 150 min, indicates a reduction relatively weak of flux 47 (L/h m^2) to 30 (L/h m^2), a decrease of 35% as the Fig. 5b shows it. It is due to the progressive accumulation of the species stopped on the surface and the pores of the membrane thus inducing phenomenon of concentration polarization and fouling partial of the pores.



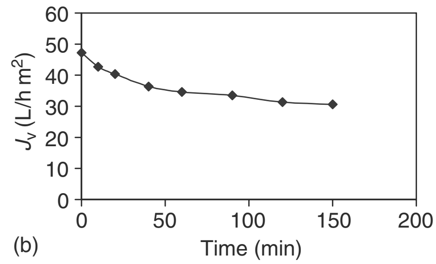


Fig. 5. Variation of the turbidity (a) and permeate flux; (b) according to the ultrafiltration time.

3.3. Coupling softening ultrafiltration

3.3.1. Coupling supernatant lime-ultrafiltration

For the test supernatant lime-ultrafiltration, the value of the permeate flux limit passes from 30 L/h m^2 for the ultrafiltration test (without addition lime) to a value of 34.6 L/h m^2 for a lime concentration of 600 mg/L, an increase of 13% (Fig. 6b).

We observe a reduction of 97% in turbidity for the coupling lime — ultrafiltration (Fig. 6a) with a final value 0.21 NTU.

3.3.2. Coupling supernatant resin-UF

An abatement of 92% in turbidity for coupling CG5-ultrafiltration, with final value equal to 0.65 NTU; 95% for the coupling CG400-ultrafiltration, a final value 0.34 NTU are observed (Fig. 7a). We noted an improvement of the permeate flux (Fig 7b). For the coupling supernatant resin-ultrafiltration, the value of the permeate flux limit increases from 30 L/h m^2 for the

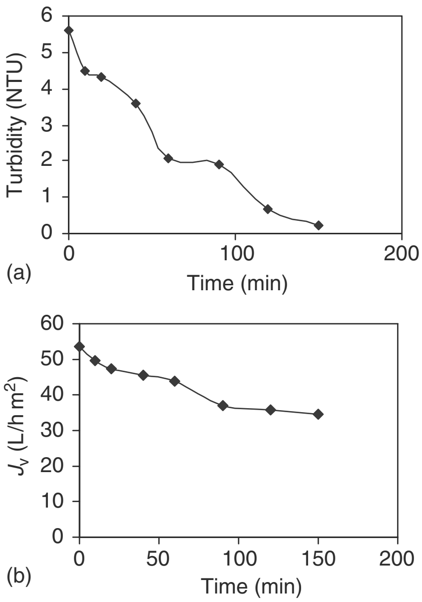


Fig. 6. Variation of the turbidity (a) and permeate flux; (b) according to the ultrafiltration time "supernatant lime + UF".

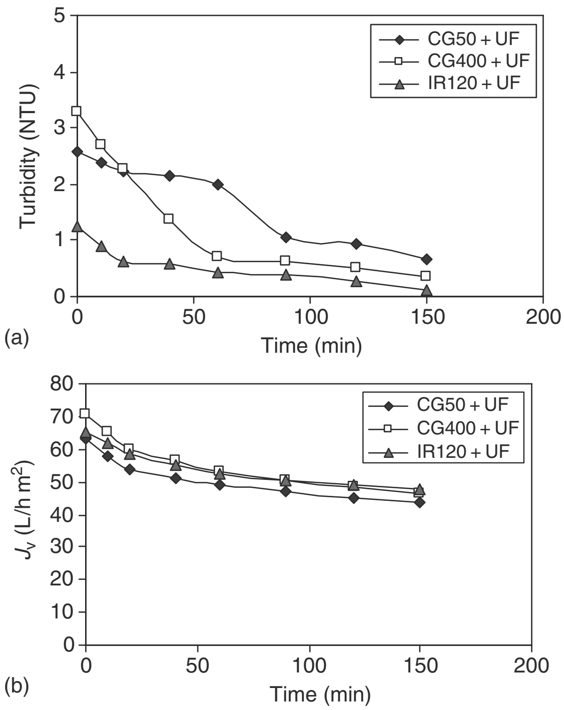


Fig. 7. Variation of the turbidity (a) and permeate flux; (b) according to the ultrafiltration time "supernatant resin Amberlite CG400, CG50, IR120 +UF".

ultrafiltration test to a value of 46 L/h m^2 for a concentration of 360 mg/L of the resin Amberlite CG 400 is an increase of 34%, 35% for resin IR120-ultrafiltration, 29.8% for resin CG50-ultrafiltration. The latter gives very good elimination compared to lime. This results in a competition between the two techniques softening ultrafiltration for the elimination of the species present (Ca^{2+}, Mg^{2+}, CO_3^{2-}).

The Figs. 8 and 9 compare the quality of the water produced according to the different conditions, we notice that total hardness in raw water is strongly decreased, a significant reduction is observed with coupling CG400-UF, and turbidity and improvement of the permeate flux for the coupling: Supernatant IR120-UF.

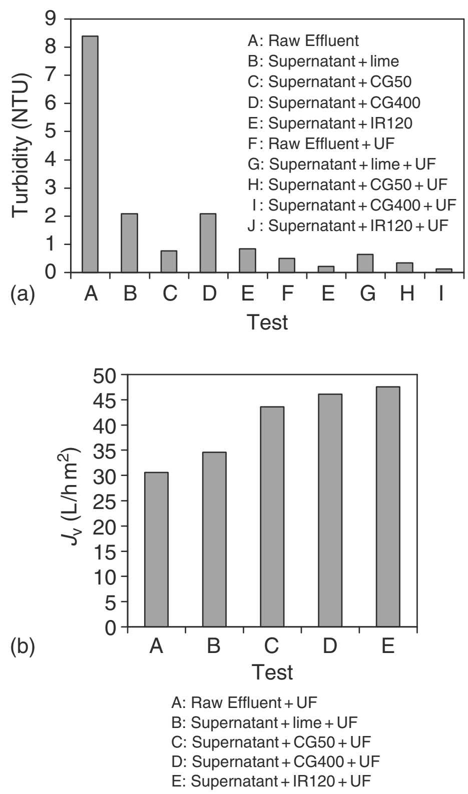


Fig. 8. Variation of turbidity (a) of limit permeate flux; (b) according to the different conditions.

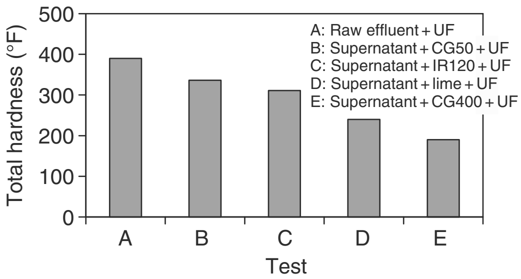


Fig. 9. Variation of the total hardness according to the various tests.

4. Conclusion

During this work, we determined the optimum conditions for decarbonatation by using lime and the resin, the coupling of the two techniques "softening ultrafiltration". This last is beneficial contribution for the pretreatment of sea water plant desalination of the Corso city. The results relative for a concentration of 600 mg/L of lime and 360 mg/L of the resin are rather satisfactory and encouraging. The best result corresponds a reduction of total hardness about: 51% in Gravel bank-test by the resin addition CG400, with a value of 190°F. A significant reduction of turbidity: 98% under test of coupling CG120-ultrafiltration, with a final value 0.13 NTU. An improvement of the permeate flux 55% for the resin IR120 ultrafiltration was observed in parallel.

References

[1] J.D. Zhang, Y.W. Liu, S.M. Gao, C.Z. Li, F. Zhang, H.M. Zen and C.S. Ye, Pilot testing of outside in UF pretreatment prior to RO for high turbidity seawater desalination, Desalination, 189 (2006) 269–277.

[2] A. Brehant, V. Bonnelye and M. Perez, Comparison of MF/UF pretreatment with conventional filtration prior to RO membranes for surface seawater desalination, Desalination, 144 (2002) 353–360.

[3] P.H. Wolf, S. Siverns and S. Monti, UF membranes for RO desalination pretreatment, Desalination, 182 (2005) 293–300.

[4] D.F. Halpern, J. McArdle and B. Antrim, UF preteatment for SWRO: pilot studies, Desalination, 182 (2005) 323–332.

[5] C.K. Teng, M.N.A. Hawlader and A. Malek, An experiment with different pretreatment methods, Desalination, 156 (2003) 51–58.