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Environmentally friendly antiscalant effective in inhibition of scale formation and dispersing organic and colloidal matter in seawater desalination plants

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ABSTRACT

The aim of the study is to evaluate the effectiveness of environmentally friendly antiscalant ADIC RO-18^{AdicGreen} in preventing the formation of scales in the reject, dispersing organic matter and inhibiting the colloidal fouling in the seawater reverse osmosis systems. The antiscalant developed is environmentally friendly because it is phosphorous and nitrogen free. Experimental tests were conducted in order to evaluate the ability of the antiscalant developed to disperse organic and colloidal matter. The results of filtration curves, operated under constant pressure (Modified Fouling Index), and the study using scanning electron microscopy with energy dispersive X-ray spectroscopy of the deposit adhered to filters, indicated that the antiscalant dosage retards filter fouling, and decreases the amount of clay retained on the filter, with respect to a filter without the presence of antiscalant. To evaluate the ability of this antiscalant developed to prevent scale formation in the reject of seawater reverse osmosis, a study in a RO pilot plant was carried out. The tests results demonstrated the antiscalant is effective in controlling inorganic scales and inhibiting the deposition of iron, aluminium, manganese and silica. A dosage of the antiscalant model and the scaling potential reduction for sparingly soluble species model were developed. The models calculate scaling potentials and recommend the minimum dosage of antiscalant to ensure the effective protection of the reverse osmosis membranes against scaling and fouling. Dosing the minimum effective antiscalant reduces operating costs for chemical treatment and minimizes treatment chemical discharge to the environment.

Keywords: Reverse osmosis; Seawater antiscalant; Colloidal and organic dispersion; Scale inhibition; Seawater; Environmental friendly antiscalant

1. Introduction

Under certain operating conditions, it is usual that the surface of the seawater reverse osmosis membranes and spacers are fouled, affecting the operating conditions. The membrane fouling causes a decrease of permeate water production, a decrease of salt rejection and an increase of differential pressure. In these cases, it is essential to reduce membrane fouling for optimum operation of seawater reverse osmosis plants.

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The performance lost of seawater membranes is mainly due to four types of fouling: adsorption of organic matter, microbiological contamination due to the growth of micro-organisms on membrane surface, plugging of the membrane surface due to deposition of particulate matter and colloidal particles and scaling and metal oxide fouling due to the precipitation of sparingly soluble salts and metal hydroxides and oxides in the rejected water [1].

Sparingly soluble salts can exceed the solubility limits in the rejected water that has highly concentrated scale components. This leads to precipitation of insoluble salts on the membrane surface. The most common scaling and fouling are calcium carbonate, calcium sulphate, calcium fluoride, calcium phosphate, strontium sulphate, barium sulphate, iron, aluminium, manganese and silica. Apart from limiting recovery to avoid exceeding solubility limits, the most common approaches followed to prevent scale formation are pH adjustment through acid addition to reduce the scaling potential, and the use of antiscalants. The antiscalants are added to feedwater at very low levels to prevent the formation of the scales in the rejected water.

In natural waters, colloidal foulants include clays, colloidal silica, hydrous metal oxides, bacteria and organic debris. Colloidal fouling is an important limiting factor of reverse osmosis system performance. Colloidal fouling of membranes is caused by the colloids deposition onto membrane surface [2]. The prevention of colloidal fouling can be done using media filtration, oxidation filtration, in-line filtration, coagulation–flocculation, cross-flow microfiltration/ultrafiltration, cartridge microfiltration and softening [3]. However, these pre-treatment processes do not remove all colloids from the feedwater. Small colloids (<2 μm) can reach the membrane system and cause membrane fouling.

Incorporation of an effective inhibitor with dispersant properties in the pre-treatment of a seawater reverse osmosis system can provide improved operating conditions. These types of products with high-performance dispersant properties minimize the agglomeration of colloids and keep the colloids suspended without settling on the membrane surface.

Antiscalants containing phosphorous in their formulation are widely used for the control of scaling in seawater desalination plants. However, their biodegradability and phosphorus content are some of the reasons for the growing concern of environmental impact that represents the discharge of these compounds into the sea. When antiscalants containing phosphorus are discharged into the sea, they can act as a nutrient source for algae and bacteria, and can lead to eutrophication [4]. Consequently, environmental regulations and the requirements for the quality brine of seawater reverse osmosis plants are becoming more restrictive with regard to discharge the chemicals used in water treatment into the sea.

In this context, ADIQUIMICA designed and developed the antiscalant ADIC RO-18^{AdicGreen} for seawater reverse osmosis systems. This antiscalant is environmentally friendly because it does not contain phosphorus or nitrogen in its composition. Other properties of this product are its non-toxicity to humans and aquatic systems, its compatibility with reverse osmosis membranes and its competitive cost compared with traditional antiscalants. ADIC RO-18^{AdicGreen} is an effective antiscalant to inhibit scale formation and disperse colloidal fouling in seawater membrane systems. The dispersant properties of ADIC RO-18^{AdicGreen} allow to improve the pre-treatment effectiveness and reduces the rate of colloidal fouling of membrane elements. The antiscalant/dispersant duality of ADIC RO-18^{AdicGreen} is a significant added value over other products that only have antiscalant properties.

The aim of the study is to evaluate the effectiveness of environmentally friendly antiscalant ADIC RO-18^{AdicGreen} in dispersing colloidal fouling and preventing the formation of scales in the rejected water of seawater reverse osmosis systems.

2. Evaluation of antiscalant effectiveness to inhibit colloidal fouling in seawater reverse osmosis plants

There are different methods to predict the colloidal fouling potential of reverse osmosis feed water. These methods include Silt Density Index (SDI) and Modified Fouling Index (MFI).

SDI is an empirical approach and potentially unreliable, which is used as an indicator of the quantity of particulate matter in the feed water, and it correlates with the tendency of fouling of reverse osmosis membranes. SDI was calculated from the rate of plugging of a filter at constant pressure. SDI is not based on any filtration mechanism and it is not proportional to particle concentration [5]. In contrast, MFI is proportional to concentration of suspended matter contained in feed water, and is based on cake filtration. Therefore, MFI is a method which is more accurate than SDI to predict fouling potential of water. In both tests, water is filtered through a 0.45-μm filter at constant pressure of 2.01 bars.

MFI is based on mechanisms of membrane filtration. The filtration process at constant pressure may include several mechanisms [6]: depth filtration, blocking filtration, cake filtration without compression and cake filtration with compression. In a filtration curve at constant pressure, when filtration time per filtrate volume (t/V) vs. volume (V) is plotted, different zones can be distinguished: the initial increase corresponds to a depth filtration and blocking filtration, followed by a cake filtration without compression [7] and the last portion of the curve corresponds to the compression of cake.

MFI is the slope of linear portion that corresponds to cake filtration without compression. The development of the MFI is consistent with Darcy's Law in which the thickness of the cake layer formed on the filter surface is assumed to be directly proportional to the filtrate volume.

Two types of MFI tests were conducted to evaluate the effectiveness of antiscalant ADIC RO-18^{AdicGreen} to disperse colloidal fouling. First test performed consisted of the filtration of a required seawater volume to reach filter collapse. Test was carried out without antiscalant treatment, and dosing antiscalant. And the second test consisted of the filtration of the same volume of seawater for both without antiscalant treatment and with antiscalant dosage. Assays were performed with seawater before the intake of a desalination plant located in the Mediterranean coast. The water was passed through a filter of 0.45 μm at a constant pressure of 2.01 bars. The temperature was controlled at 25°C. The time required to collect volumes of 500 mL was measured. The results of the two tests were:

2.1. Filtration of a required seawater volume to reach filter collapse

Tests were carried out by passing the required volume of seawater through the 0.45-μm filter, without antiscalant treatment and with dosage of ADIC RO-18^{AdicGreen}, until the filters collapsed. The filtration stopped when the last portion of the filtration curve was reached, which corresponds to the cake filtration with compression.

Fig. 1 shows the filtration curves at constant pressure for both without antiscalant treatment and with dosing antiscalant tests. In both curves, the cake filtration with compression was distinguished, which corresponds to the last points of the curve where its slope changes. In the curve without antiscalant treatment, the change in slope occurred at a volume of 2.5 L, while when antiscalant was dosed, the slope of the curve changed at a volume of 5 L. The results indicated that the dosage of the antiscalant ADIC RO-18^{AdicGreen} retards the filter collapse.

MFI is calculated from the slope of the linear portion of each filtration curve. Fig. 2 shows the slope of each linear regression of the t/V vs. V curves. A steeper slope means a higher MFI, in other words, more fouling and higher resistance of the formed cake on filter surface. The MFI value without antiscalant treatment was 186.6 s/L^2. The MFI was reduced to 40.2 s/L^2 when antiscalant was dosed. These results indicate the colloidal fouling potential of seawater decreased by 78.46% when antiscalant ADIC RO-18^{AdicGreen} was dosed. A significant improvement in filtrate volume was obtained.

2.2. Filtration of the same volume of seawater for both without antiscalant treatment and dosing antiscalant tests

Two MFI tests were carried out in this study; first, without antiscalant treatment and, then, ADIC RO-18^{AdicGreen} was dosed. In both tests, the same volume of seawater was passed through 0.45-μm filter. The filtration curve obtained during the test without antiscalant treatment, reached the cake filtration with compression. In contrast, when the antiscalant was dosed, the filter did not collapse and the filtration curve reached the cake filtration without compression. After each MFI test, a scanning electron microscopy and energy dispersive X-ray spectroscopy analysis (SEM-EDX) was used to study the elemental composition, crystal structure and morphology of deposits and scales deposited on the each filter surface.

SEM allowed obtaining high-resolution images of the chemical and topographical features of the foulants and particles on the filters surface. The captured images were analysed in terms of different elements, EDX was used for elemental analysis and chemical characterization at a particular location in a sample (point analysis), and it was used to map the distribution of elements in a selected area. The elemental mapping allowed analysing simultaneously all the elements present in an area, and evaluate the relative amounts of each element. The density and intensity of the dots of mapping are proportional to the amount of each element. During treatment of the filter samples for SEM-EDX analysis, samples were coated with graphite to make them conductive, therefore, carbon peak in the EDX spectrum was not taken into account when fouling composition was studied.

The SEM images at 50× magnification of the filters surface, without and with antiscalant dosage (Fig. 3), showed the presence of branch-shaped precipitate distributed throughout the surface, which corresponded to sodium chloride.

The filter without antiscalant treatment experienced severe fouling when seawater was filtered. EDX analysis and elemental mapping of SEM image (2500× magnification) of filter surface (Figs. 4(a) and 5)

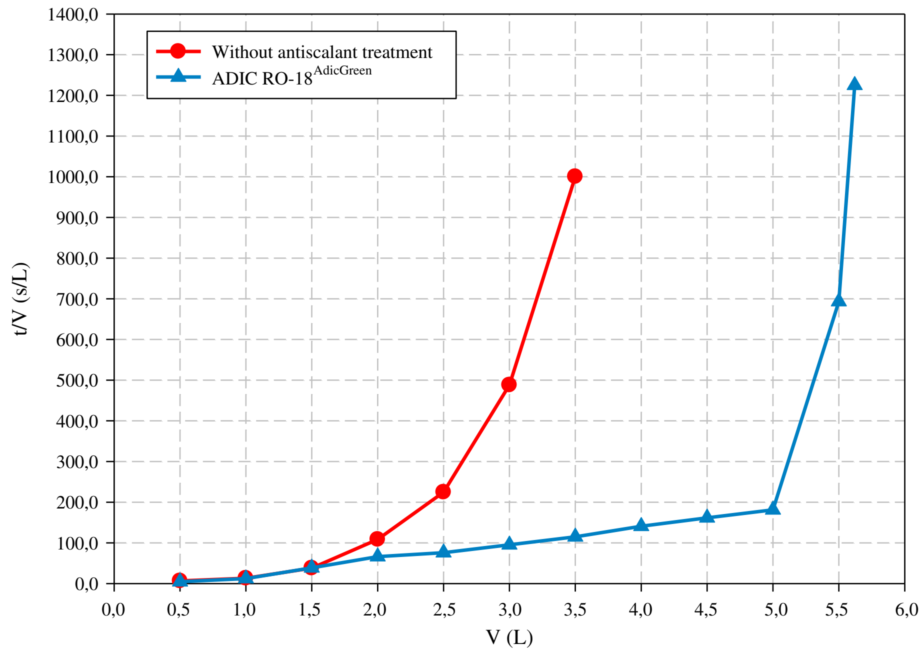


Fig. 1. Filtration curve at constant pressure without and with antiscalant treatment.

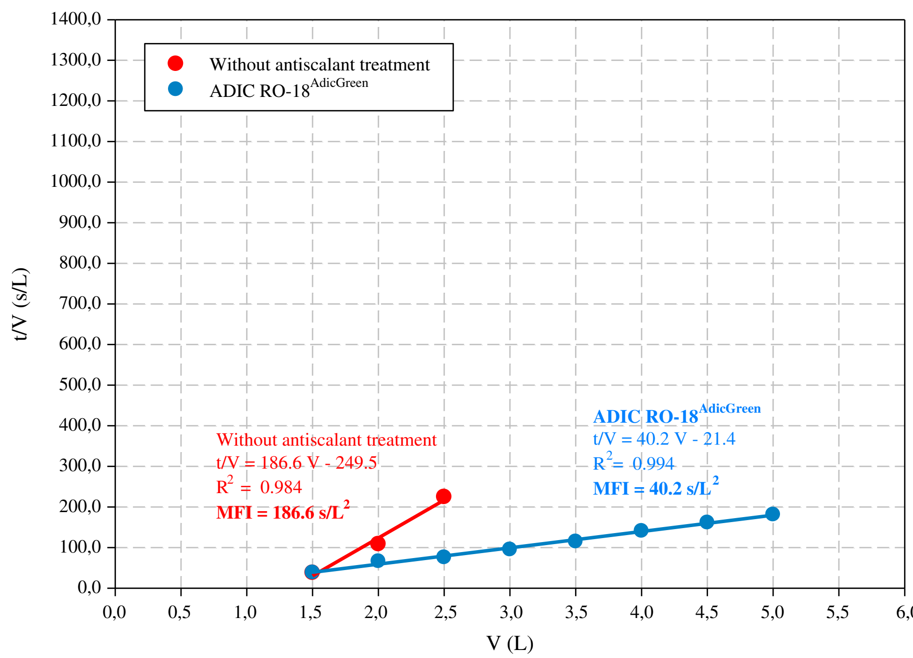


Fig. 2. MFI calculation from filtration curves at constant pressure without and with antiscalant treatment.

indicated the filter surface was covered with a layer composed mainly of clay, which is colloidal (silica, aluminium, iron, magnesium, calcium and potassium). There are different types of clay, the most common is composed of silica structures, where some silicon ions are replaced by aluminium, giving rise the aluminosilicates. Other types of clay contain in their structure cations such as aluminium, magnesium, iron, potassium, calcium and sodium. All the elements that composed the clay were present in the same location, indicating that they were part of the same deposit. Above this layer of clay, and at a much lower degree,

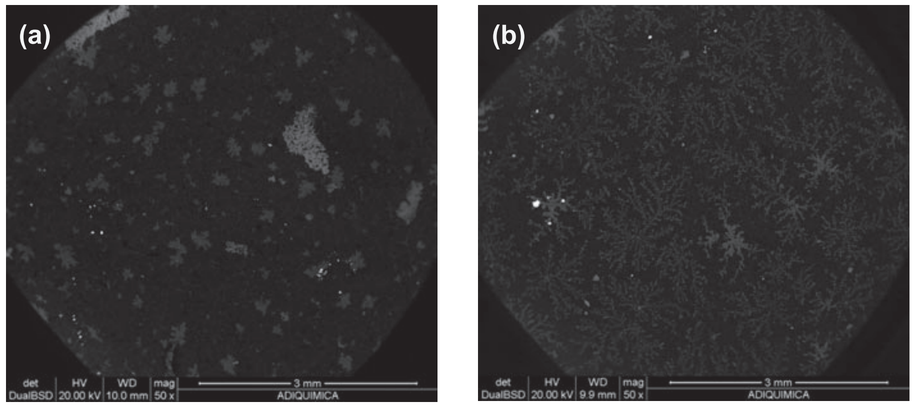


Fig. 3. SEM images of MFI filter surfaces (50× magnification): (a) without antiscalant treatment and (b) with antiscalant dosage.

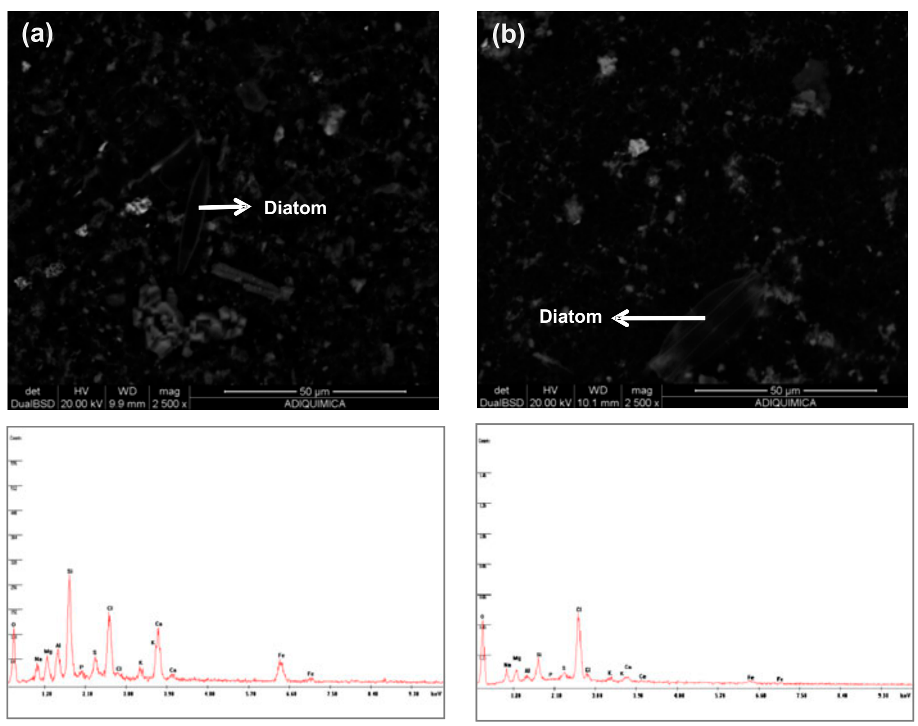


Fig. 4. SEM microphotographs (2500× magnification) and EDX analysis of MFI filter surfaces: (a) without antiscalant treatment and (b) with antiscalant dosage.

insoluble sulphur compounds, calcium carbonate scales and insoluble phosphorous compounds were detected. Diatoms were also identified. The structure of the cell wall of diatom contains silica.

The EDX spectrum and elemental mapping results of SEM image (2500× magnification) of filter surface when antiscalant was dosed (Figs. 4(b) and 6), showed low levels of fouling on the filter surface. The deposit was mainly composed of clay (silica, aluminium, iron, magnesium, calcium and potassium). Trace levels of insoluble sulphur and phosphorus compounds were detected. Diatoms presence was also observed.

Tables 1 and 2 show semi-quantitative results of the elemental composition for the area of the filters surface without and with the dosage of ADIC RO-18^{AdicGreen} shown in Fig. 4(a) and (b), respectively. The semi-quantitative elemental composition was calculated from EDX spectrum, and was expressed in

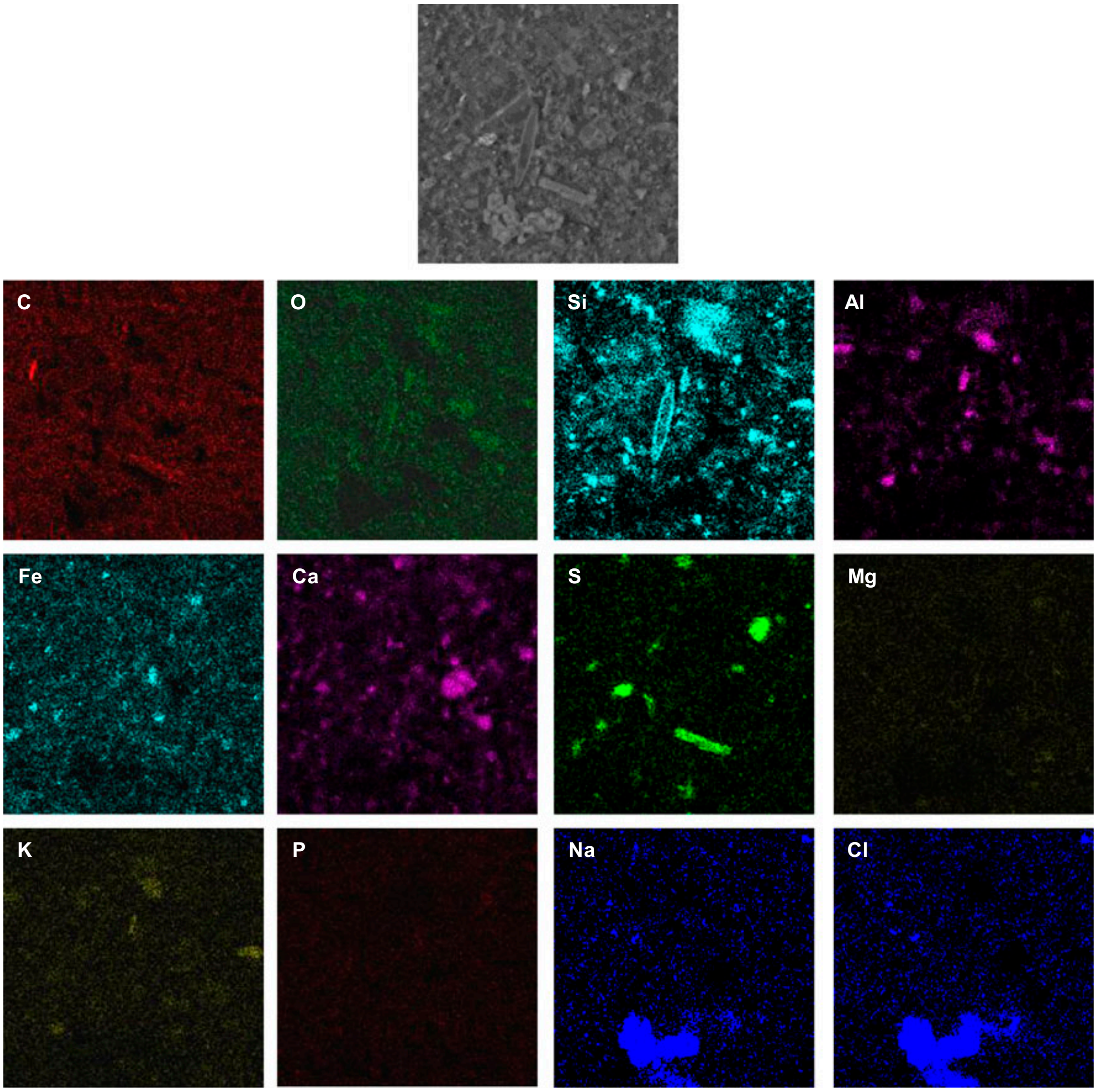


Fig. 5. Elemental mapping for the area of the MFI filter surface without antiscalant treatment shown in Fig. 4(a).

units of both weight percentage and atomic percentage. In both filters, the elements composing fouling were: silica, aluminium, iron, calcium, sulphur, magnesium, potassium and phosphorous. The other detected elements came from sodium chloride, filter-building components and graphite that coated the sample. When antiscalant was dosed, the percentage values of elements composing the fouling were much lower compared with the filter without antiscalant treatment. In both cases, the clay was the main foulant, because the sum of percentage of its constituents had greatest value. Table 3 shows the change in the weight percent of each element, between the filter without treatment and the filter treated with antiscalant. When ADIC RO-18^{AdicGreen} was dosed, there was a decrease in constituents of the clay of about 80% with respect to the filter without treatment. A decrease of 57.39% of insoluble sulphur compounds and a decrease of 80.64% of insoluble phosphorus compounds were also occurred. Calcium, which is a constituent of the silicate and calcium carbonate, decreased by 85.36%.

The results of MFI tests indicated that the antiscalant ADIC RO-18^{AdicGreen} dosage prevents early collapse of the filter, retards filter fouling and decreases the amount of clay retained on the filter surface, compared with a filter without the presence of antiscalant.

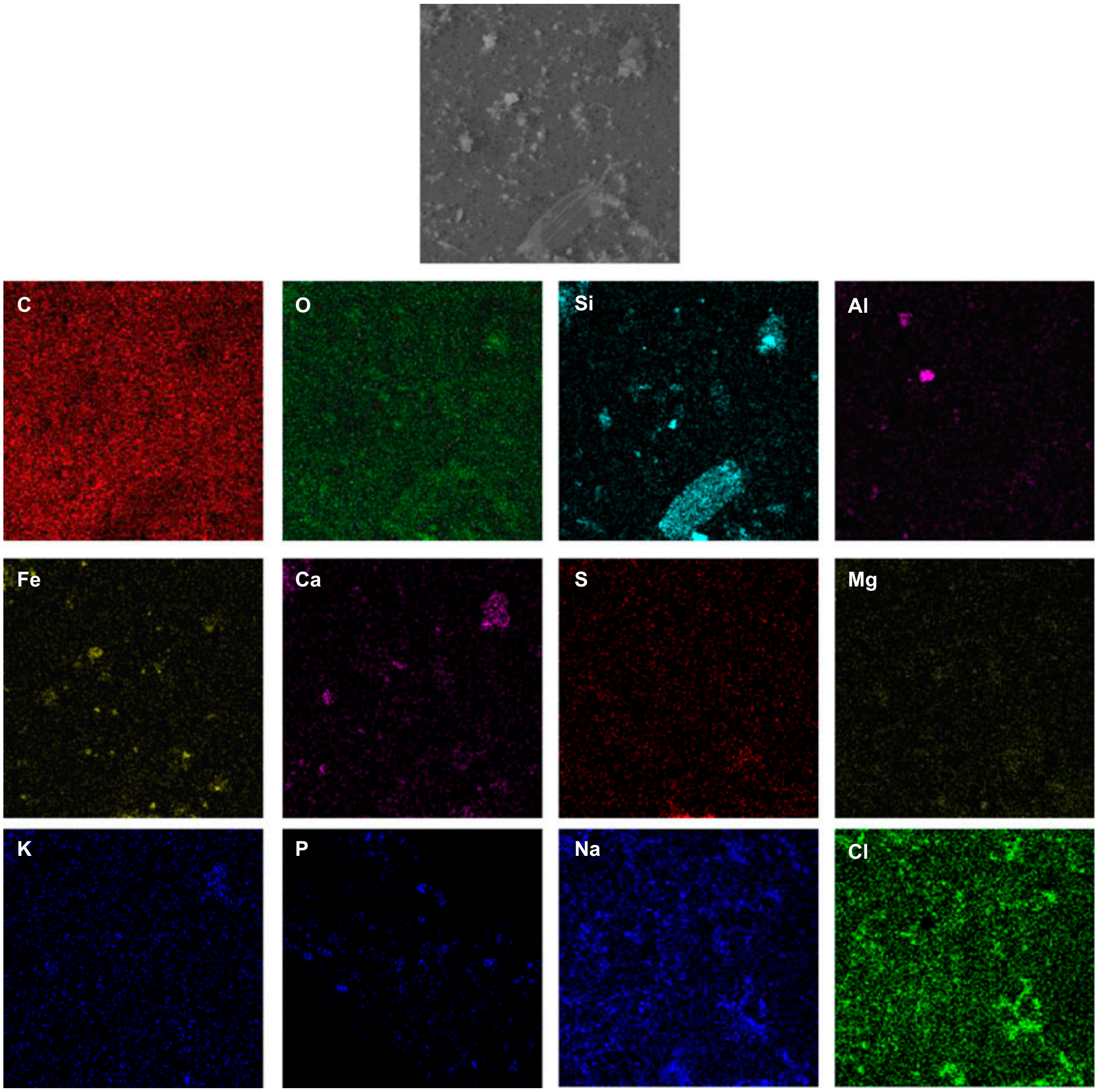


Fig. 6. Elemental mapping for the area of the MFI filter surface with antiscalant dosage shown in Fig. 4(b).

Table 1
Weight percent and atomic percent of elements for the area of the MFI filters surface without antiscalant treatment shown in Fig. 4(a)

	Element											
	C	O	Si	Al	Fe	Ca	S	Mg	K	P	Na	Cl
Weight (%)	44.93	16.70	7.64	2.41	7.89	6.42	1.76	2.05	1.43	0.62	1.90	6.26
Atomic (%)	63.38	16.70	4.61	1.51	2.39	2.71	0.93	1.43	0.62	0.34	1.40	2.99

Table 2
Weight percent and atomic percent of elements for the area of the MFI filters surface with the dosage of antiscalant shown in Fig. 4(b)

	Element											
	C	O	Si	Al	Fe	Ca	S	Mg	K	P	Na	Cl
Weight (%)	60.80	23.90	1.67	0.38	1.34	0.94	0.75	0.98	0.58	0.12	1.48	6.96
Atomic (%)	72.14	21.25	0.85	0.20	0.34	0.33	0.33	0.57	0.21	0.06	0.92	2.79

Table 3
Change percent of the weight percent of each element, between the filter without treatment and the filter treated with antiscalant

	Element							
	Si	Al	Fe	Ca	S	Mg	K	P
Weight (%)	−78.14	−84.23	−83.02	−85.36	−57.39	−52.20	−59.44	−80.64

3. Evaluation of antiscalant efficacy to inhibit the scale formation in the rejected water of seawater reverse osmosis plants

3.1. Simulation study of scale formation in the reject of a seawater reverse osmosis plant

A study to determine the scaling potential in the rejected water of a seawater reverse osmosis plant was performed. Table 4 shows the water chemistry of feedwater and rejected water at 45% recovery. The composition of the water corresponds to feedwater after pre-treatment of a desalination plant located in the Mediterranean coast.

A study was performed with scientific software ADICRO to simulate the water behaviour in a reverse osmosis system. The input variables were the feedwater composition, temperature, plant recovery and membranes used. ADICRO software calculates osmotic pressure, ionic strength and the values of the solubility products for sparingly soluble species corrected according to ionic strength. These values are used to calculate saturation levels (SL), Langelier Saturation Index, Stiff & Davis Index, fouling index and scaling potentials to predict the risk of membrane scaling or fouling. The software also recommends the most effective antiscalant and the optimal dosage to protect membranes against scaling phenomena and deposit formation. The program determines the optimal operating range, and indicates whether the treated water will be within allowable limits for the different scaling potentials. The program also calculates the amount of sulphuric or hydrochloric acid or base required to decrease or increase the feedwater pH to reach the desired pH.

Based on the feedwater analysis in Table 4 and operating at recovery of 45%, a study of the scaling potential for sparingly soluble species in the concentrate water was conducted using ADICRO scaling prediction software. Fig. 7 shows the scaling potentials without antiscalant treatment at a temperature of 20˚C. The scaling potentials are expressed as the percentage of the maximum admissible limit for the SL and fouling indexes. A scaling potential higher than 100% indicates the SL for a compound is greater than the maximum permissible limit for this SL, and the compound will tend to precipitate. The simulation results indicated that the solubilities at 20˚C of calcium carbonate ($CaCO_3$), iron (Fe) and manganese (Mn) would be exceeded in rejected water without antiscalant treatment. For other compounds, scaling potentials were within admissible limits and the plant could be operated without risk of scale formation.

3.2. Experimental study in reverse osmosis pilot plant to evaluate the efficacy of the antiscalant to inhibit the scale formation in the rejected water of seawater reverse osmosis plant

To evaluate the effectiveness of the antiscalant ADIC RO-18^{AdicGreen}, a dynamic test was conducted in a continuous flow pilot RO plant, which is composed of one pressure vessel housing a 2540-size element. Assay was carried out with a total recycle of both the concentrate and permeate to the feed vessel, so as to maintain a constant composition. This test was conducted using synthetic water to work in totally controlled conditions. Separate solutions containing anions and cations were added to the seawater that

Table 4
Water chemistry of feedwater and rejected water at a recovery of 45%

Parameter	Feedwater	Simulated rejected water at a recovery of 90% (software ADICRO)
pH	8.19	8.32
Calcium	475 mg/L Ca	861 mg/L Ca
Magnesium	1,496 mg/L Mg	2,713 mg/L Mg
Sodium	13,521 mg/L Na	24,528 mg/L Na
Potassium	464 mg/L K	842 mg/L K
Barium	<0.005 mg/L Ba	<0.005 mg/L Ba
Strontium	8.0 mg/L Sr	14.5 mg/L Sr
Iron	0.089 mg/L Fe	0.162 mg/L Fe
Aluminium	0.011 mg/L Al	0.020 mg/L Al
Manganese	0.319 mg/L Mn	0.578 mg/L Mn
Sulphate	3,111 mg/L SO_4	5,642 mg/L SO_4
Chloride	24,095 mg/L Cl	43,701 mg/L Cl
Fluoride	0.190 mg/L F	0.345 mg/L F
Bicarbonate	129.6 mg/L HCO_3	216.6 mg/L HCO_3
Carbonate	8.0 mg/L CO_3	23.6 mg/L CO_3
CO_2	1.0 mg/L H_2CO_3	1.0 mg/L H_2CO_3
Nitrate	5.8 mg/L NO_3	10.5 mg/L NO_3
Silica	0.337 mg/L SiO_2	0.621 mg/L SiO_2
Phosphate	<0.01 mg/L PO_4	<0.01 mg/L PO_4
Ionic strength (FI)	0.783	1.383

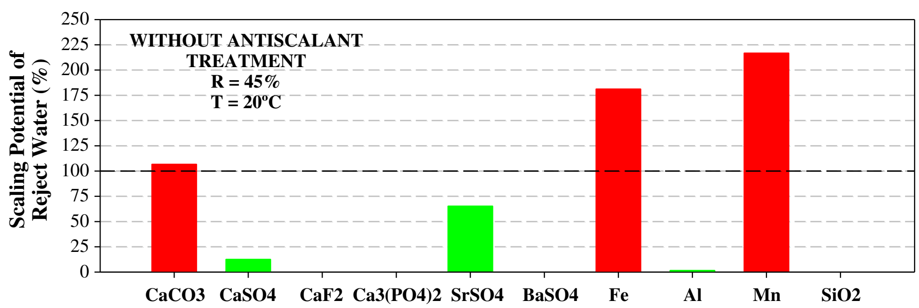


Fig. 7. Scaling potential of rejected water (recovery = 45%) without antiscalant treatment at $T = 20$°C.

already contained the antiscalant, to obtain a water that simulated rejected water at a recovery of 45% shown in Table 4, with scaling potentials shown in Fig. 7. Sodium chloride was added also to achieve an ionic strength equivalent to the rejected water. The RO element Filmtec SW30-2540 was used during the test. The RO pilot plant operated at a recovery of 8%. The water pH was controlled at 8.32, corresponding to the pH of the rejected water obtained from simulation using the software ADICRO (Table 4). The water temperature was controlled at 20°C using a cooling system.

To study the efficacy of ADIC RO-18^{AdicGreen} to inhibit scale formation, the performance of the reverse osmosis with antiscalant dosage was evaluated for 21 d. The following operating parameters were monitored during the test: normalized permeate flux, normalized salt rejection, feed pressure, pressure drop between feed and brine streams (Delta P), pH and temperature. A complete chemical analysis of the feed and permeate was performed periodically. At the end of the test, the element was autopsied and samples of membrane were analysed using SEM-EDX technique to study the chemical composition, crystal structure and morphology of the possible inorganic deposits and scales deposited on the membrane surface.

The normalized parameters are the best indicators of membrane fouling. The evaluation is carried out analytically by standardizing operating data in accordance with the standard method ASTM D 4516 Standard Practice for Standardizing Reverse Osmosis Performance Data [8].

Figs. 8–10 show the behaviour of normalized permeate flow per unit of membrane area (permeate flux), normalized salt rejection and Delta P for 21 d of operation, respectively, with the dosage of ADIC RO-18^{AdicGreen}. The results show that the normalized flux, normalized salt passage and Delta P remained stable; there were no variations in the normalized parameters. These results indicated that the antiscalant was effective to avoid membrane scaling.

To validate the effectiveness of the antiscalant, the element was autopsied at the end of the test, and samples of membrane were analysed using SEM-EDX technique. Fig. 11 presents the SEM images and EDX spectrum from the reverse osmosis membrane used during the test with antiscalant dosage. The autopsy results indicated that inorganic scales and colloidal fouling were not found on membrane surface. The oxygen and sulphur correspond to building components of polyamide membrane polymer and polysulfone support.

The results of the study in RO pilot plant indicated that the antiscalant ADIC RO-18^{AdicGreen} is effective in controlling inorganic scales and prevents the membrane colloidal fouling in seawater reverse osmosis systems.

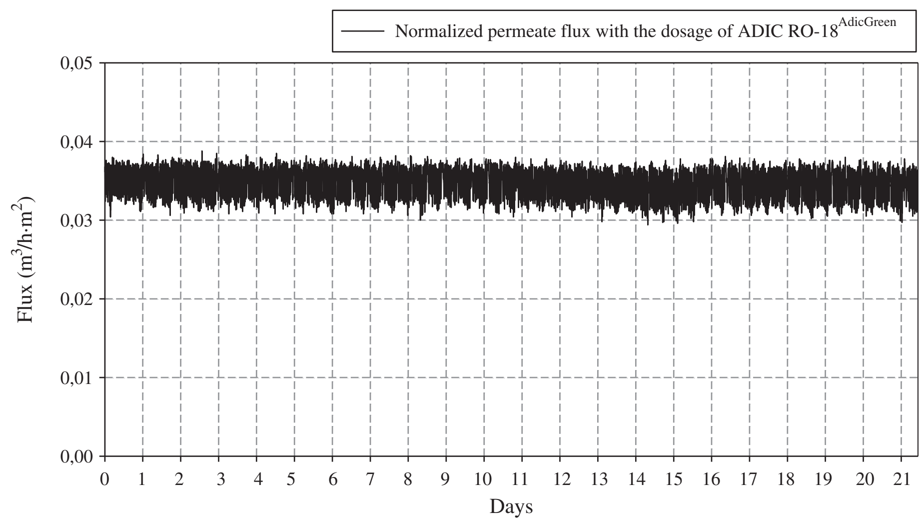


Fig. 8. Normalized permeate flux with the dosage of antiscalant for 21 d of operation.

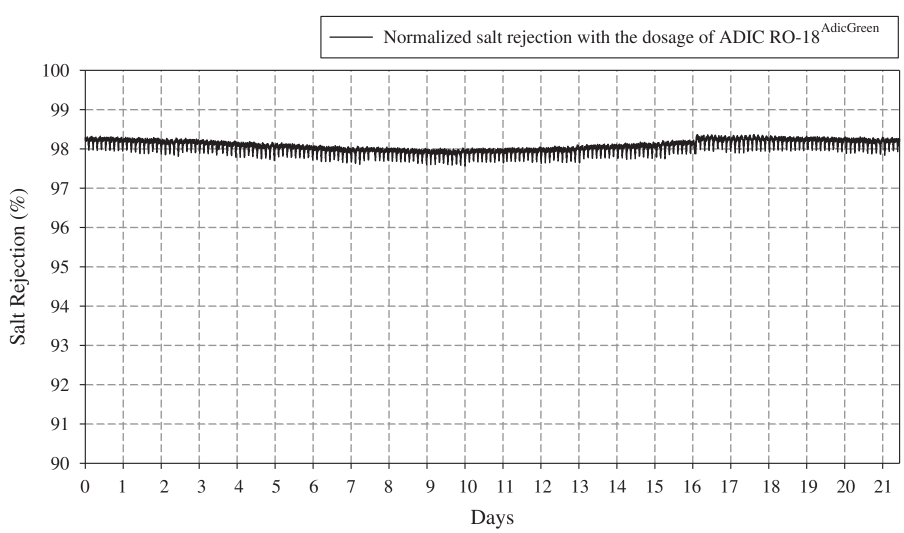


Fig. 9. Normalized salt rejection with the dosage of antiscalant for 21 d of operation.

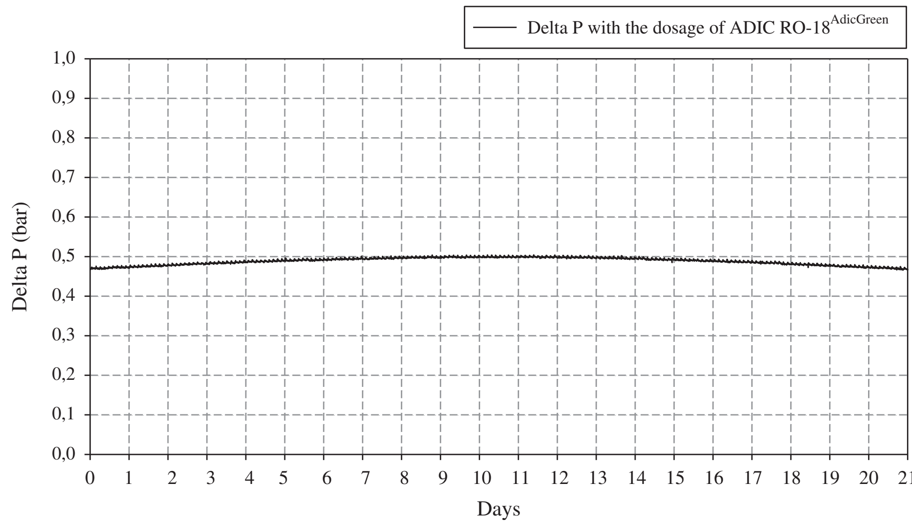


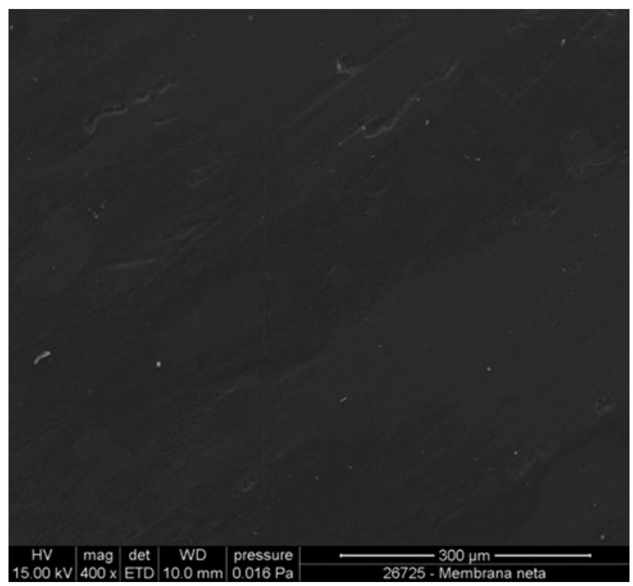
Fig. 10. Delta P with the dosage of antiscalant for 21 d of operation.

4. Development of antiscalant model

A dosing model for ADIC RO-18^{AdicGreen} was developed. The model calculates the optimum effective antiscalant dosage to inhibit the formation of scales in the rejected stream. The mathematical model was developed from data obtained from RO pilot plant experimental runs and field data. The antiscalant was tested under various solution supersaturation conditions and antiscalant concentrations. The model predicts the dosage for scale control based upon water chemistry and operating parameters. The experimental results allowed modelling the reduction of scaling potentials for sparingly soluble species as a function of the concentration of antiscalant.

The dosage of antiscalant model, the scaling potential reduction model and the knowledge acquired in the experimental stage were incorporated into the software ADICRO. The program calculates scaling potentials and recommends the optimal dosage of antiscalant to ensure the effective protection of the seawater reverse osmosis against scaling and fouling. The dosage of the minimum effective antiscalant concentration reduces operating costs for chemical treatment, minimizes chemicals discharge to the environment and prevents the over and underdosing of the antiscalant.

Fig. 12 shows the reduction of scaling potentials in the rejected water of the seawater reverse osmosis at a recovery of 45% (Table 4) and temperature of 20˚C with required dose rate of antiscalant. Scaling potentials for the calcium carbonate, iron and manganese were reduced to values lower than 100% with antiscalant dosing. The reverse osmosis membranes were fully protected against scale formation on the membrane surface.



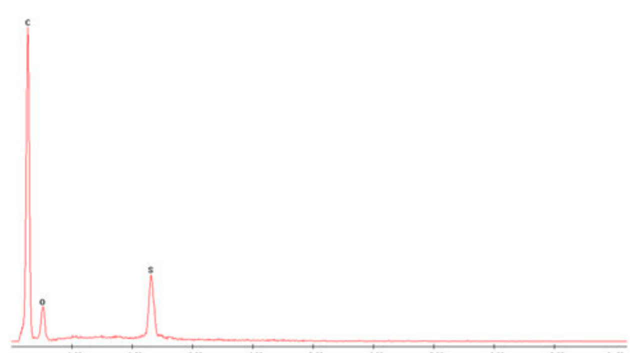


Fig. 11. SEM microphotograph (400× magnification) and EDX analysis of the reverse osmosis membrane surface used during the test with the dosage of antiscalant.

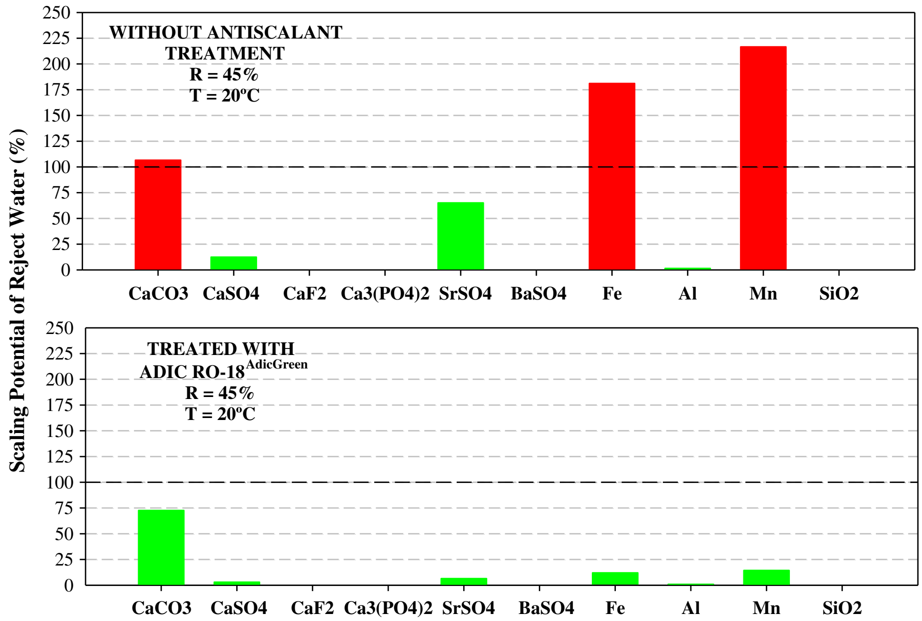


Fig. 12. Scaling potentials of rejected water (recovery = 45%) without and with antiscalant treatment at $T = 20°C$.

5. Conclusions

ADIC RO-18AdicGreen is an environmentally friendly antiscalant to be used in seawater reverse osmosis systems. It does not contain phosphorus or nitrogen in their composition. The antiscalant is effective in inhibiting colloidal fouling and prevents the formation of scales in the rejected water. The antiscalant/dispersant duality of ADIC RO-18AdicGreen is a significant added value over other products that only have antiscalant properties.

The evaluation of the effectiveness of ADIC RO-18AdicGreen to inhibit colloidal fouling in seawater reverse osmosis plant shows antiscalant prevents early collapse of filters, retards filter fouling and decreases the amount of clay retained on the filter surface, compared with a filter without the presence of antiscalant.

The antiscalant ADIC RO-18AdicGreen is effective in controlling scale formation in the rejected water and preventing the membrane colloidal fouling in seawater reverse osmosis systems. The results of study in RO pilot plant shows antiscalant is effective in preventing calcium carbonate, iron and manganese precipitation, and avoiding the settling of colloids on the membrane surface.

A dosing model for ADIC RO-18AdicGreen was developed. The mathematical model was developed from data obtained from RO pilot plant experimental runs and field data. The dosage model was incorporated into the software ADICRO.

The software ADICRO is a useful tool for optimizing the dosage of antiscalant as a function of feedwater analysis, temperature and plant recovery. The software recommends the minimum effective antiscalant dosage to protect the membranes against scaling and fouling. Dosing the minimum effective antiscalant reduces operating costs for chemical treatment and minimizes treatment chemical discharge to the environment.

Acknowledgements

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References

[1] L. Weinrich, C.N. Haas, M.W. LeChevallier, Recent advances in measuring and modeling reverse osmosis membrane fouling in seawater desalination: A review, J. Water Reuse Desalin. 3(2) (2013) 85–101.
[2] M.T. Brunelle, Colloidal fouling of reverse osmosis membranes, Desalination 32 (1980) 127–135.
[3] Filmtec Membranes Tech Manual Excerpts, Colloidal Fouling Prevention, Form No. 609-00307-702QRP (2002).
[4] C. Fritzmann, J. Löwenberg, T. Wintgens, T. Melin, State-of-the-art of reverse osmosis desalination, Desalination 216 (2007) 1–76.

[5] E. Gasia Bruch, M. Busch, S.G. Salinas Rodríguez, M.D. Kennedy, Improvement of Fouling Indices Measurements and Modeling of their Relevance, International Desalination Association World Congress, Perth, September 4–9, 2011.
[6] J.C. Schippers, J. Verdouw, The modified fouling index, a method of determining the fouling characteristics of water, Desalination 32 (1980) 137–148.
[7] S.F.E. Boerlage, M.D. Kennedy, M.P. Aniye, E.M. Abogrean, G. Galjaard, J.C. Schippers, Monitoring particulate fouling in membrane systems, Desalination 118 (1–3) (1998) 131–142.
[8] American Society for Testing Materials (ASTM), Standard Practice for Standardizing Reverse Osmosis Performance Data, ASTM Designation D 4516-00, Annual Book of ASTM Standards, vol. 11.02, 2010.