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New antiscalant for reverse osmosis plants

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ABSTRACT

A new antiscalant CrestoPro R493C has been developed to effectively control multiple scales such as calcium carbonate, calcium sulphate, iron, silica, etc. This product was tested in a reverse osmosis (RO) plant in Northern China using river water with TDS 710 ppm and pH 7.7, with a recovery of 70%. The major fouling problems in this plant were $CaCO_3$, $BaSO_4$, and iron, even when using conventional antiscalant which was locally manufactured. The major issue at this site was the high cleaning frequency and short life of the RO membranes. This was resolved by using 1 ppm of CrestoPro R493C and the case history will be presented. Furthermore, advances have been made on antiscalant technology, which will be introduced in this paper.

Keywords: Antiscalant; Reverse osmosis; Scale; Tablet technology; Brackish water; Cleaning; CrestoPro

1. Introduction

Separation methods that are used for different waters such as seawater, brackish water, industrial waste water, etc., are predominantly based on thermal or membrane technology [1]. The more common throughout the world is reverse osmosis (RO) which is membrane based on today's economic. Most RO plants that are designed have appropriate pre-treatment systems such as multi-media filtration, sedimentation, coagulation, etc. In addition, coagulants and polyelectrolytes are used in the sedimentation process which are then removed in the pre-treatment system with the final polishing stage by the cartridge filter [2]. However, some of the soluble coagulants or polyelectrolytes can enter the RO plant with detrimental effects on the membrane. The other additive that is used is biocides, in particular sodium hypochlorite which kills biological material but any excess remaining sodium hypochlorite is neutralised by the addition of slightly excess sodium bisulfide. Again, this is carried out prior to the cartridge filter which functions as the final physical filter for the raw water before it enters the RO plant as feed water [3].

The impurities that can be found in feed waters can be organic, inorganic, and particulate. These can be deposited on the RO membrane and foul the membrane such that its efficacy is reduced or lost and can damage the membrane such that the product water quality is poor. The particulate material is usually minimised due to the pre-treatment system in place. The typical organics is usually soluble or in some instances is reduced due to the pre-treatment system. The major problem is scaling due to the soluble inorganic ions present such as calcium, magnesium, carbonate, sulfate, silica, etc., that are present results in oversaturation of these ions which results in precipitation as the feed water is concentrated due to the removal of pure water (called product water) under pressure. In most cases, the higher the pressure applied to the feed water results in greater recovery of product water but this can significantly enhance the potential for scale formation in the bulk solution phase and on the membrane surface. The potential for deposition on the membrane surface is more prominent than in the bulk solution phase due the cross-polarisation layer.

The scales that are generally found are calcium carbonate, calcium sulfate, iron salts, silica, and many more as it is dependent on the water quality. To control or prevent the precipitation process specialised antiscalants are used that are compatible with membrane [4]. The chemistry of these antiscalants can be phosphonate or polymers based on carboxylic acids. These carboxylic acids can be based on maleic

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acid or acrylic acid with or without the inclusion of monomers to provide specific or multi-function scale control. The supplier of these antiscalants use sophisticated software which determines the potential scales that are likely to form for a given feed water chemistry under the operating parameters including the membrane types for a specific RO plant to provide the specific antiscalant and its dose of use.

CREST Water (Singapore) has developed a bespoke software program called CrestRODose. It can predict the potential scaling species in the concentrate and select the most suitable antiscalant to control those potential scales at an optimum dose rate. CrestRODose has been used in this work and the results will be shown in the case history section.

To demonstrate the ability of antiscalant to work effectively, it must be tested in an RO plant that is in current operation. CREST Water has developed a new antiscalant CrestoPro R493C based on specialised polycarboxylic acid that is able to effectively control multiple scales such as calcium carbonate, calcium sulphate, iron, silica, etc. To demonstrate its ability to efficiently control scale deposition, it was tested in an RO plant in Northern China using river water which had scaling issues and required to be frequently cleaned. The objective of this paper is to demonstrate that the new antiscalant CrestoPro R493C was effective in controlling the deposition in the plant and reducing the frequency of cleaning compared with the traditional antiscalant that was in use.

2. Case history – trial with CrestoPro R493C

A RO plant in Northern China was used to evaluate CrestoPro R493C. The system parameters are:

1) RO capacity: 2 × 100 MT/h
2) Water type: river
3) Recovery rate: 70%
4) Membrane type: DOW BW30-400
5) Raw water source: river water (Table 1)
6) Pre-treatment process: coagulation/sedimentation/multimedia filter/UF/cartridge filter

Table 1
Analysis of feed water, that is, river water

Parameter	Analysis
pH	7.71
Sodium, mg/L	121
Calcium hardness, mg/L (as $CaCO_3$)	40.25
Magnesium, mg/L	25.2
Iron, mg/L	0.05
Carbonate, mg/L	Not detected
Bicarbonate, mg/L (as $CaCO_3$)	205.5
Chloride, mg/L	112
Sulfate, mg/L	178
Silica, mg/L	5.7
Barium, mg/L	0.16
Strontium, mg/L	0.73

CrestRODose determined the major fouling problems using the water chemistry in Table 1 in this plant to be calcium carbonate, barium sulfate, and iron, with saturation indices at 1.12, 46.54, and 3.32, respectively, in the concentrate.

The field test with 1 mg/L of CrestoPro R493C was carried out and the following parameters were monitored for the feed water, concentrate, and permeate:

a) pH
b) Conductivity
c) Calcium ion concentration
d) Magnesium ion concentration
e) Alkalinity
f) Flow rates
g) Pressures

The scale inhibition rate was calculated using the equation shown below:

Scale inhibition rate = CF calcium/CF chloride × 100%

where CF = System concentration factor based on the chloride concentrations in the feed, concentrate (%)

Concentration factor (CF chloride) = Chloride level in the concentrate/chloride level in the feed

Concentration factor (CF calcium) = Calcium level in the concentrate/calcium level in the feed

2.1. Operational results prior to the trial with CrestoPro R493C

Previous antiscalant product is local RO antiscalant at 5 ppm dosed in the feed. The customer operated with this local manufactured antiscalant of 5 ppm because this was recommended by the antiscalant supplier for the conditions of operation of this RO plant.

Fig. 1 shows that the feed and permeate flow rates are declining throughout the period from 12th June 2016 to 19th November 2016. This was due to the fouling taking place on the membranes even though a local antiscalant was being used to control scale at 5 ppm. The blue arrows in Fig. 1 indicate the time when acid cleaning was carried out and hence the sudden drop in both the feed and permeate flows. During this period, the chemical cleaning was an average of 1.5/month.

The first stage pressure drop increases quickly from 0.15 to 0.3 Mpa as shown in Fig. 2 whereas, the secondary stage pressure drop is maintained between 0.15 and 0.1 Mpa. Even after each chemical cleaning (represented by arrows in Fig. 2) the first stage pressure drop is between 0.2 and 0.35 Mpa. The fouling in RO plant is difficult to remove by conventional chemical cleaning. This is most likely due to organic fouling.

The calculated desalination rate of RO membrane (Fig. 3) is found to be unacceptable at around 90%–95%. The high frequency of chemical cleaning shortens the life of membrane.

2.2. Operational results after the trial with CrestoPro R493C

During the trial, CrestoPro R493C was dosed at 1 ppm into the feed.

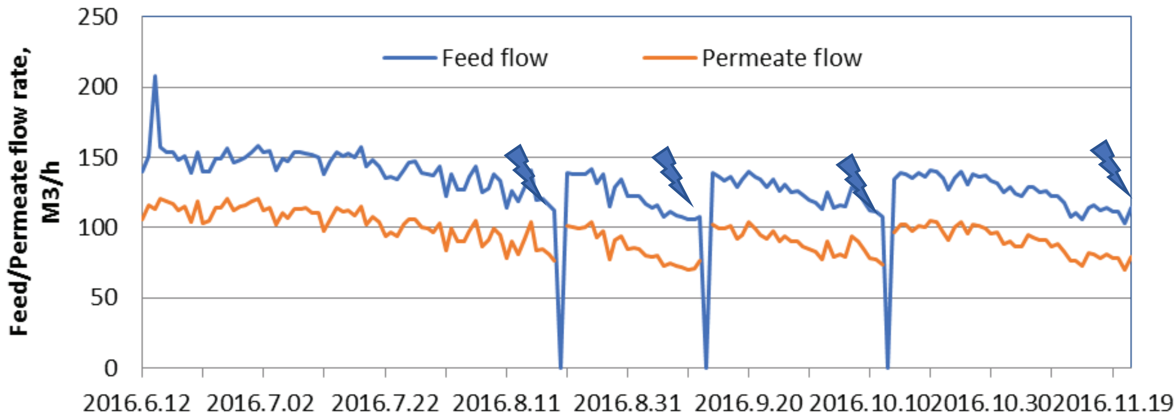

Fig. 1. Feed and permeate flow rate when a local antiscalant was used.

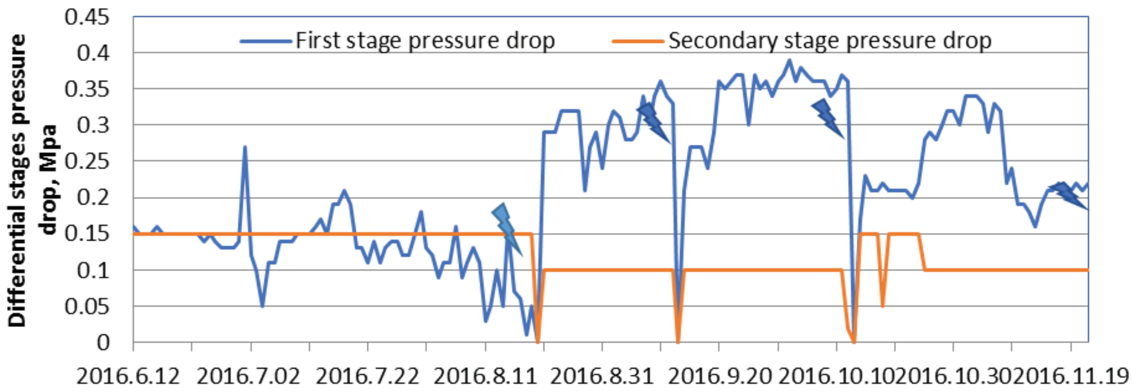

Fig. 2. Pressure drop when a local antiscalant was used.

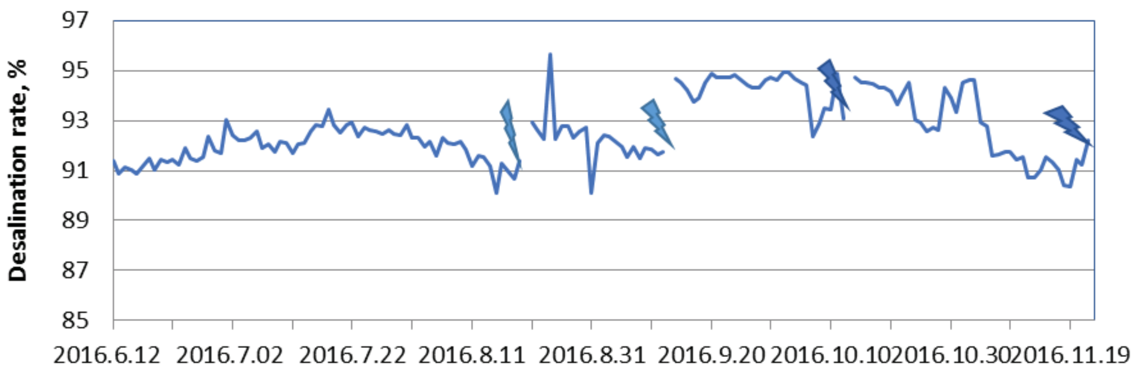

Fig. 3. Desalination rate when a local antiscalant was used.

The results in Fig. 4 show the feed and permeate flow when using CrestoPro R493C antiscalant in this RO plant. The feed and permeate flow rates were found to be stable. During this period from 24th November to 21st December no chemical cleaning was required indicating that 1 ppm of CrestoPro R493C was much more effective in controlling scale deposition than the conventional antiscalant that was being used at 5 ppm.

Fig. 5 shows the secondary stage pressure drop decreases from 0.15 Mpa to less than 0.1 Mpa indicating that the scaling is being controlled but could be having an on-line cleaning of the membranes but further work is required to confirm this.

By using CrestoPro R493C, the desalination rate of RO membrane maintains at around 92%–94% as shown in Fig. 6 indicating effective operation of the RO plant.

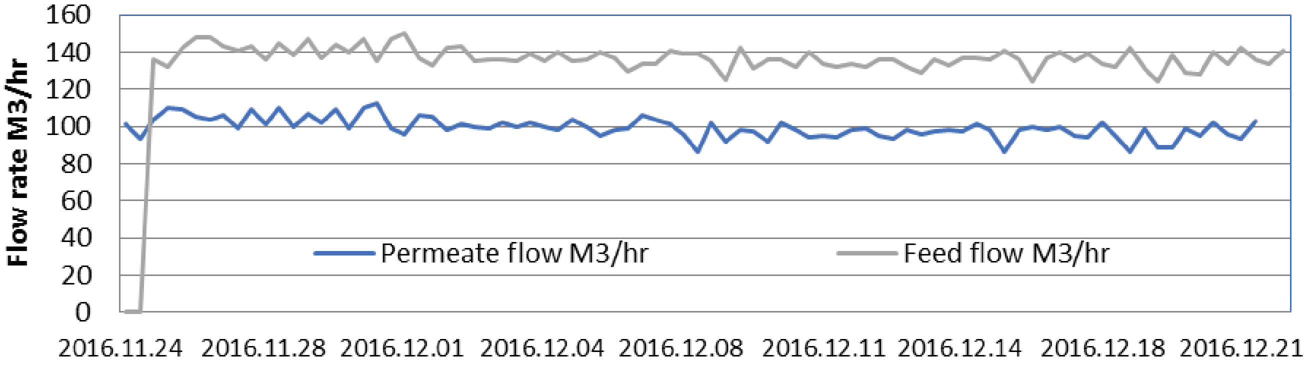

Fig. 4. Feed/permeate flow rate when CrestoPro R493C was used as antiscalant.

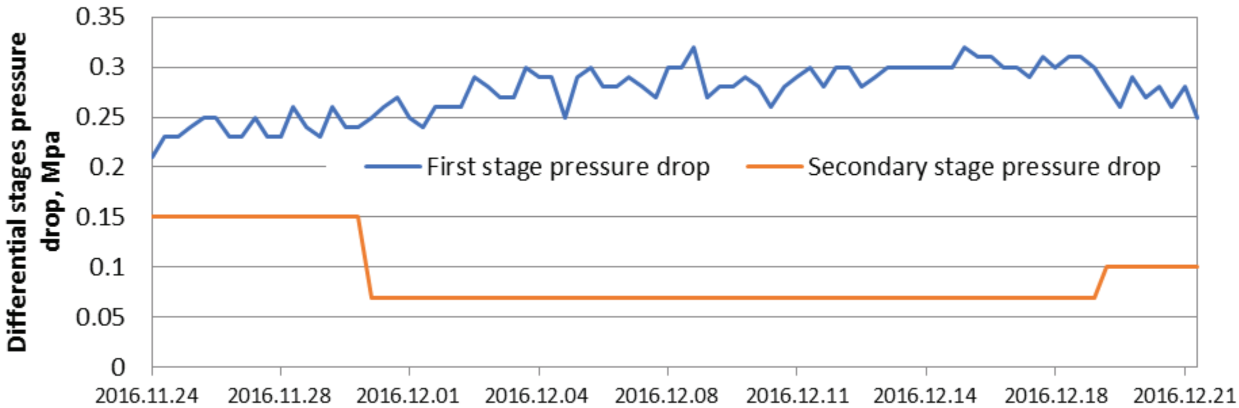

Fig. 5. Pressure drop when CrestoPro R493C was used.

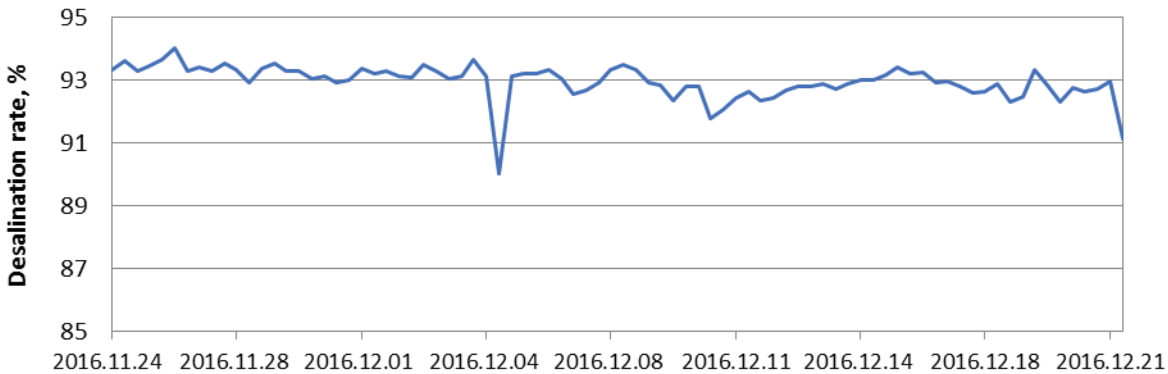

Fig. 6. Desalination rate when CrestoPro R493C was used.

After using CrestoPro R493C antiscalant in this RO plant, the average scale inhibition rate of CrestoPro R493C was 99.63%.

This was a field trial requested by the client to satisfy that CrestoPro R493C can be used in their RO plant for 1 month and demonstrating the benefits. The customer was unwilling to share further data as they would like to keep this operational data confidential.

3. New antiscalant technology based on solid tablet

A new antiscalant technology has been developed based on a solid tablet (Fig. 7) which is highly concentrated compared with conventional antiscalants that are currently being used for RO plants. This new tablet is easy to use as it dissolves rapidly in the antiscalant tank. It is safe to handle and requires less storage space and hence lower inventory. However, for the operators of RO plants it becomes more

Fig. 7. Example of solid tablet antiscalant.

economical as savings are made in shipping and storage costs.

This solid tablet antiscalant has approximately 1.7 times more actives compared with CrestoPro R493C; compared with CrestoPro R493C, it is a unique polymeric antiscalant, as compared with single-component antiscalant, its performance is 1.75 times to 2 times better than CrestoPro R493C. Furthermore, it is three to four times more concentrated than conventional concentrated phosphonate and exhibits multifunctional scale control properties.

Further developments for this tablet technology are being carried out and will be presented in a future paper.

4. Application – case history with CrestoPro R594

The field trial has been done in Shandong Dezhou. The feed water is sourced from local underground and the analysis data of feed water is listed as below.

The RO system parameters are:

1) RO capacity: 80 MT/h
2) Water type: underground water
3) Recovery rate: 80%
4) Membrane type: DOW BW30-400
5) Raw water source: underground water (Table 2)
6) Pre-treatment process: multimedia filter/cartridge filter

The major fouling problems determined by CrestRODose for this feed water in Table 2 for this RO plant was calcium carbonate and iron, with saturation indices at 2.44 and 9.67, respectively, in the concentrate.

These tablets dissolved in product water within 20 min of mixing in the antiscalant tank. CrestoPro R594 was dosed at 1 ppm into the feed for this test in the RO plant.

The feed flow rate and permeate flow rate were stable during the test period as shown in Fig. 10. This indicates that the permeate flow rate was between 65 and 68 m^3/h, with a system recovery rate of 79%–83%. This is the normal operation of the RO plant with no adverse effect on the fouling of the membranes during the use of CrestoPro R594.

Fig. 11 shows the differential stage pressure drop is stable during the test period with CrestoPro R594. First stage pressure drop is maintained between 0.2 and 0.22 Mpa whereas, secondary stage pressure drop is maintained between 0.06 and 0.08 Mpa which is within normal operation of the RO plant.

The desalination rate in Fig. 12 shows a gradual increase from 97.4% to 97.8% which is within the normal operation of the RO plant.

Table 2
Analysis of feed water, that is, underground water

Parameter	Analysis
pH	8.3
Conductivity, μs/cm	1,526
Calcium hardness, mg/L (as $CaCO_3$)	24
Magnesium, mg/L	54
Iron, mg/L	0.1
Carbonate, mg/L	Not detected
Bicarbonate, mg/L (as $CaCO_3$)	918
Chloride, mg/L	107.2
Sulfate, mg/L	159.4

Fig. 8. Photographs of tablet CrestoPro R594.

Fig. 9. Operator dissolving the tablet, CrestoPro R594, in the product water.

This new tablet technology can be easily used and is found to have no detrimental effect on normal operation of a RO plant.

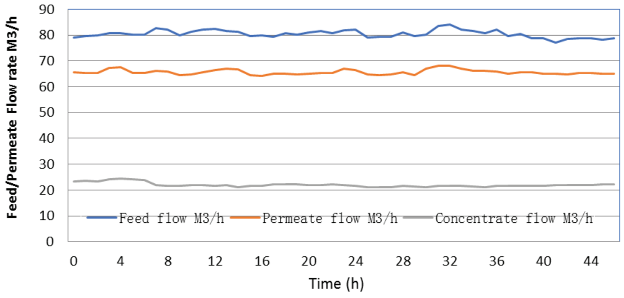

Fig. 10. Feed/permeate flow rate when CrestoPro R594 was used as antiscalant.

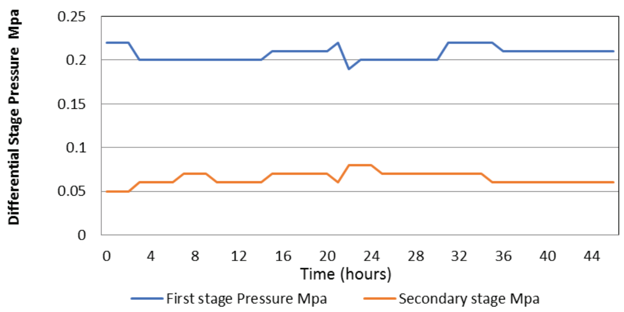

Fig. 11. Pressure drop when CrestoPro R594 was used.

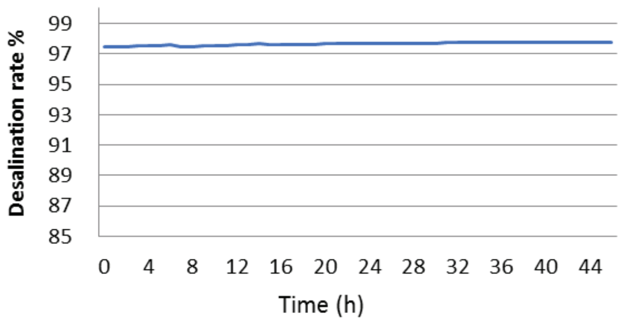

Fig. 12. Desalination rate when CrestoPro R594 was used.

5. Conclusion

This study shows that CrestoPro R493C antiscalant is effective at controlling multiple inorganic scales including iron at low dose levels in RO plant in Northern China using river water. By controlling the scaling, there is reduced frequency of chemical cleaning of the RO plant thus maintaining longer period of plant operation, extending the life time of the RO membranes and reducing chemical cleaning cost.

Introduction of new antiscalant tablet technology CrestoPro R594 was found to have no detrimental effect on the operation of the RO plant when it was substituted for the conventional antiscalant that was being used. This new tablet technology will improve the economics of using antiscalants as it is more concentrated, safe and easy to handle, store and reduce shipping costs thus reducing the overall operational cost for the plant operator. Further developments for this technology will be presented in a future paper. Once further tests are completed in larger RO plants compared with conventional antiscalants that are in use will be presented in a future paper.

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