CASE STUDY: THE USE OF A NOVEL ANTISCALANT TO PREVENT IRON FOULING IN A BRACKISH WATER RO SYSTEM

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Abstract:

A municipality in Texas had been operating its new reverse osmosis (RO) trains for only a few months when it started experiencing severe decline in flux and an increase in salt passage. Membrane cleaning did not restore performance.

Cartridge filter analysis found heavy iron loading. Membrane autopsies revealed heavy iron hydroxide fouling across the entire length of the system, with the concentrate elements experiencing the worst flux decline and severe surface abrasion.

The plant was designed with the RO system being fed from a 50,000 gal (189 m^3) storage tank. The feedwater contained a significant concentration of iron which was completely soluble under anoxic conditions but oxidized to insoluble ferric hydroxide in the atmospheric feed tank. The concentrations of iron exiting the feed tank were highly variable as precipitated iron sludge would slough off from the bottom of the tank.

While bypassing the feed tank and installing a VFD on the well pump would have been the ideal solution, the plant needed to operate, and such a major undertaking could not be performed overnight. A chemical solution was therefore needed to resolve the issue.

After verifying the cause of the fouling by membrane autopsy, an iron-specific CIP chemical was used to restore performance. A novel iron-control antiscalant was then put online, upstream of the feed tank, resulting in stable normalized performance for a full year, and eliminating the need for further cleaning.

This case study describes how the owner, the consulting engineer and the chemical solutions provider worked together to troubleshoot, select and validate the optimal chemistry, and most importantly, make changes in the process to allow for the correct application of the chemistry and restore system performance.

Introduction

A newly constructed municipal brackish water RO plant in Texas was experiencing severe fouling and deteriorating permeate quality. The owners of the plant contracted NorrisLeal Engineering to study the problem and identify a solution. In turn, NorrisLeal invited American Water Chemicals (AWC) to assist in identifying the cause and alleviating the problem.

The plant had a very standard design. Groundwater was pumped into a 50,000 gal (189 m^3) atmospheric storage tank, allowing the three RO trains to receive a steady supply of feedwater, regardless of the number of trains that were operating. Pretreatment consisted only of 5 µm cartridge filters, and each train had a dedicated scale inhibitor dosing pump.

Iron was immediately identified as being a contributor to the problem, as the cartridge filters were loaded with an orange-colored deposit. An inspection of the membrane ends also found heavy loading of an orange deposit.

Analysis

A membrane autopsy identified various issues. As expected, the membranes were heavily fouled with iron hydroxide fouling, but the last stage tail element also had some light calcium carbonate deposits as well as stainless steel debris. The origin of the stainless steel was determined to be from the system's piping which had been corroding. The piping was constructed of 304 stainless steel, despite the feed chloride concentration being almost 300 ppm. The last stage tail element also exhibited localized delamination in the form of blistering. However, dye testing determined that the majority of the loss in salt rejection was due to abrasion from the iron hydroxide particulates scouring the membrane surface.

An analysis of the groundwater consisting of a 50/50 blend from two wells found iron levels to be 0.24 ppm. However, an analysis of water from the storage tank found a much higher iron concentration of 0.37 ppm, which was entirely filterable using a 0.1 µm filter. It became apparent that ferric hydroxide was settling at the bottom of the tank, causing iron levels to be inconsistent with those of the source water. The SDI could not be determined as the filter fouling rate was too high for even a 5-minute run.

Since water was pouring in from the top of the tank, it was being efficiently aerated, causing oxidation of the dissolved ferrous iron. The iron after the cartridge filters measured at 0.14 ppm, suggesting that about half the iron was getting removed by filtration. The iron in the concentrate measured at 0.18 ppm. Since the system was operating at 75% recovery, the iron should have concentrated to 0.56 ppm, suggesting that about 70% of it was depositing on the membranes as a foulant.

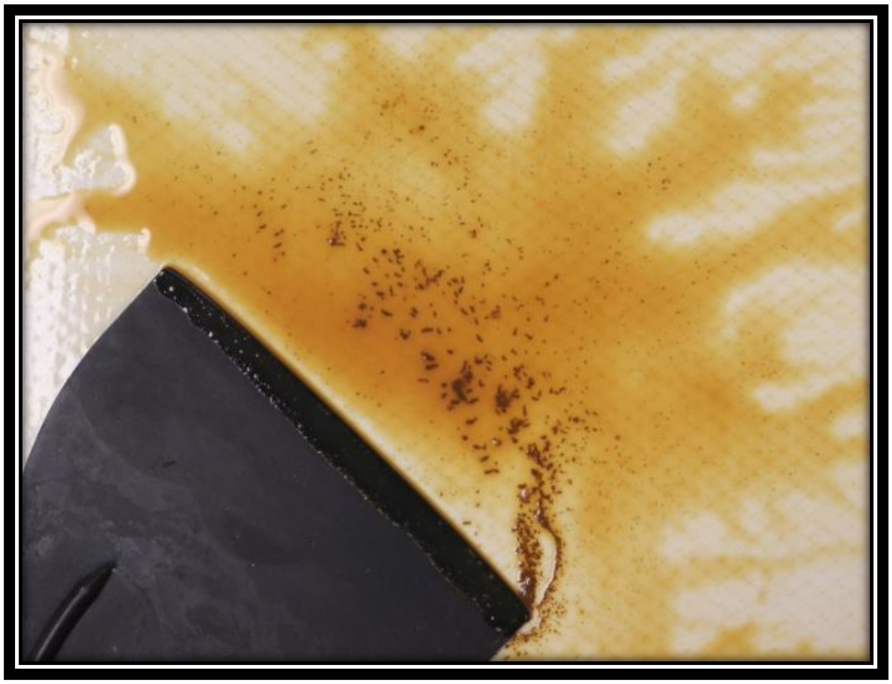


Figure 1: Iron was deposited throughout the membrane surface, with deposition being heaviest near the concentrate end of the tail element

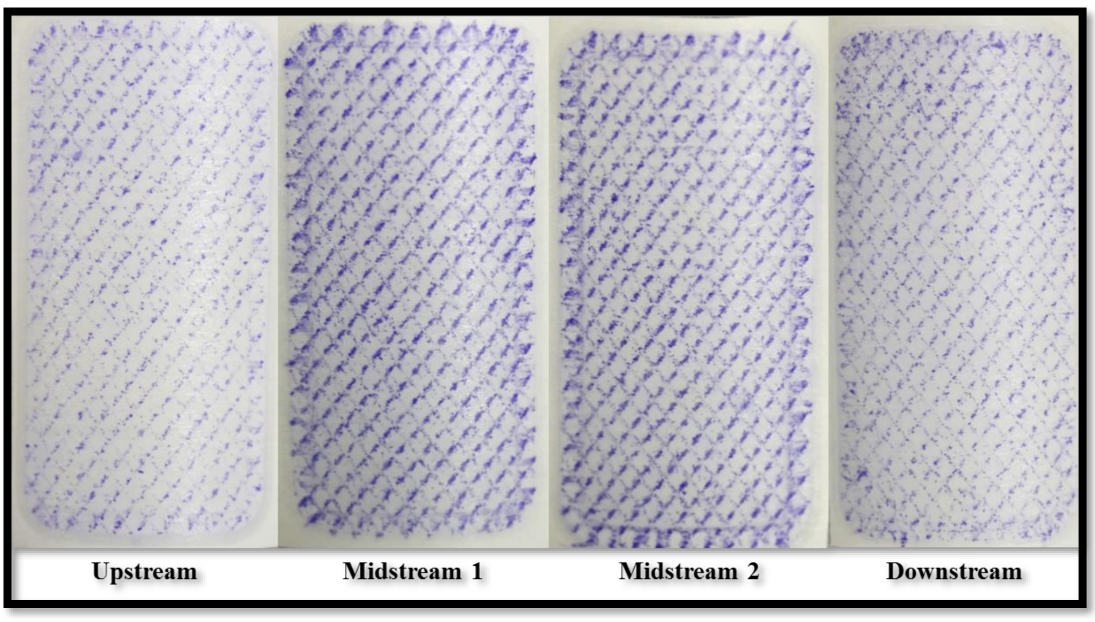


Figure 2: Dye testing found severe surface abrasion at the feed spacer contact points where most of the iron deposits had built up.

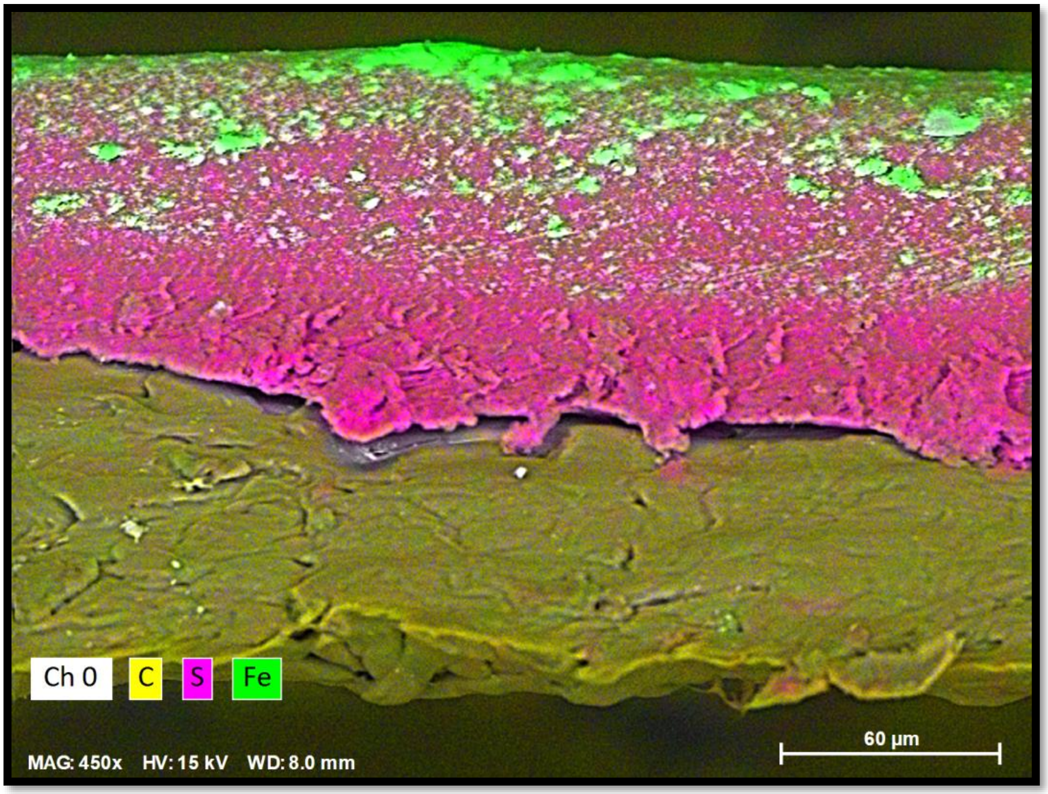
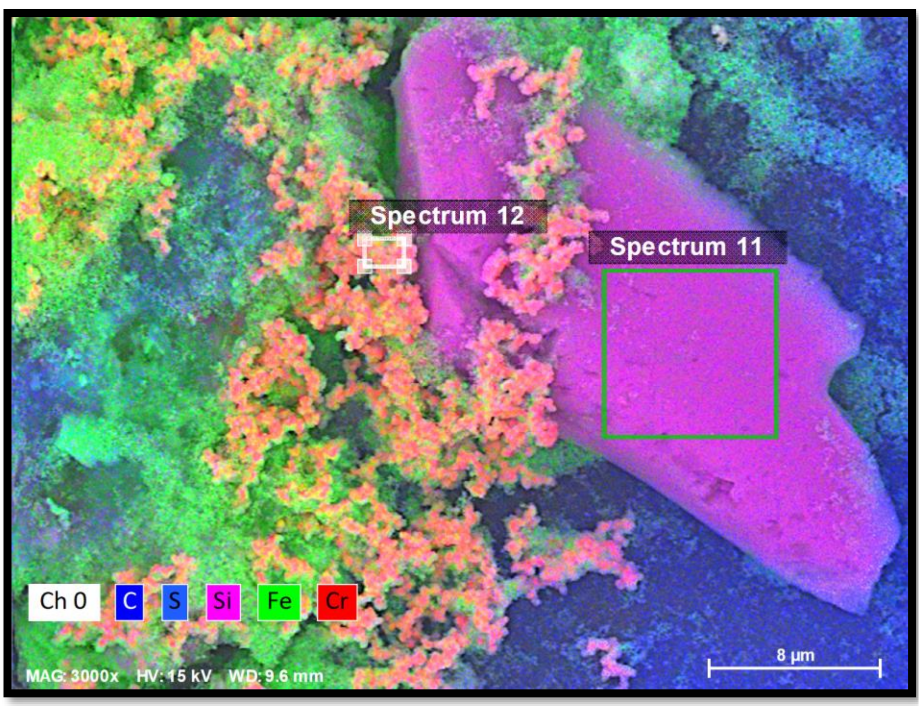


Figure 3: Superimposed Elemental Imaging of the membrane cross section shows an even layer of iron deposited across the membrane surface.



Spectrum 11

Element	Atom [%]
Carbon	45.36
Oxygen	40.16
Sulfur	1.06
Sodium	0.13
Aluminium	0.20
Silicon	11.89
Iron	0.98
Calcium	0.16
Phosphorus	0.07
	100.00

Carbon and Oxygen Ignored

Spectrum 11

Element	Atom [%]
Sulfur	7.34
Sodium	0.88
Aluminium	1.34
Silicon	82.00
Iron	6.85
Calcium	1.10
Phosphorus	0.48
	100.00

Spectrum 12

Element	Atom [%]
Carbon	41.69
Oxygen	46.44
Sulfur	1.13
Sodium	0.33
Aluminium	0.31
Silicon	3.20
Chlorine	0.16
Iron	2.75
Phosphorus	0.42
Calcium	0.88
Magnesium	0.10
Chromium	2.58
	100.00

Carbon and Oxygen Ignored

Spectrum 12

Element	Atom [%]
Sulfur	9.55
Sodium	2.75
Aluminium	2.55
Silicon	26.84
Chlorine	1.38
Iron	23.52
Phosphorus	3.55
Calcium	7.43
Magnesium	0.82
Chromium	21.60
	100.00

Figure 4: Superimposed Elemental Imaging shows iron deposits and stainless-steel debris from corroding interstage 304SS piping. A large silt particle is also visible in the image.

Projections and Simulations

The water quality and system design were entered into the Proton® projection software and iron hydroxide was found to be the only foulant of significant concern. However, controlling the iron exiting the storage tank was too challenging because of the variability; the settled iron hydroxide would slug in at extremely high concentration every time an additional train would come online.

Since the iron entering the storage tank was always a known and consistent value, it was only logical to control the iron entering the tank to prevent it from precipitating. The antiscalant would also have to have strong dispersive properties in order help remove iron that was already in the tank, and to prevent fouling of the tail elements as the iron would concentrate along the length of the system.

A new antiscalant was designed for this application, and lab simulations were performed to validate its performance as well as determine the optimal dosage.

Application

The existing antiscalant injection point was located downstream of the RO feed tank. A chemical injection quill was used to feed antiscalant which was located upstream of each RO train cartridge filter and downstream of each RO train feed valve. The dosing pumps were tied to each RO skid and dosed only when each train was running.

The antiscalant injection point was relocated upstream of the existing RO feed tank. A chemical static mixer was also added to the existing piping between the well and RO feed tank. The dosing pumps, which had previously been tied to the individual skids, were now tied to the well pumps, so that antiscalant would only be dosed when the wells were running.

The storage tank was flushed to reduce the amount of iron buildup, and the system was restarted with the new antiscalant upstream of the storage tank.

The existing inter-stage piping which had initially developed pin-hole leaks was replaced with 316L stainless steel spools as the deterioration became more severe and cleaning of the membranes became more inevitable.

The three RO trains were cleaned with a specialty high pH cleaner to remove organic and biological fouling, followed by a specialty iron cleaner.

Results

The SDI values of the RO feed from the storage tank were monitored daily. There was a clear reduction in SDI with time, as the iron deposits in the tank was dispersed into smaller colloidal particles, and the newly oxidized iron was inhibited from precipitating.

The plants operators were also trained on entering data for normalization and started to keep record of the plant's performance. One year later, the plant continues to operate at a steady rate with no further decline in permeability and no further loss in salt rejection.

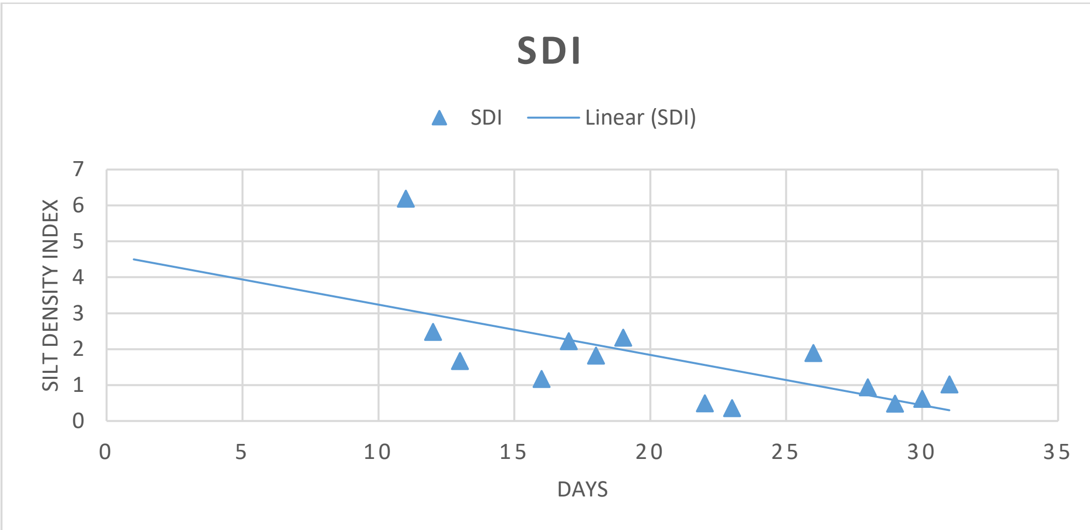


Figure 5: SDI values declined with time once the dosing point of the new antiscalant was moved upstream of the RO feed tank.

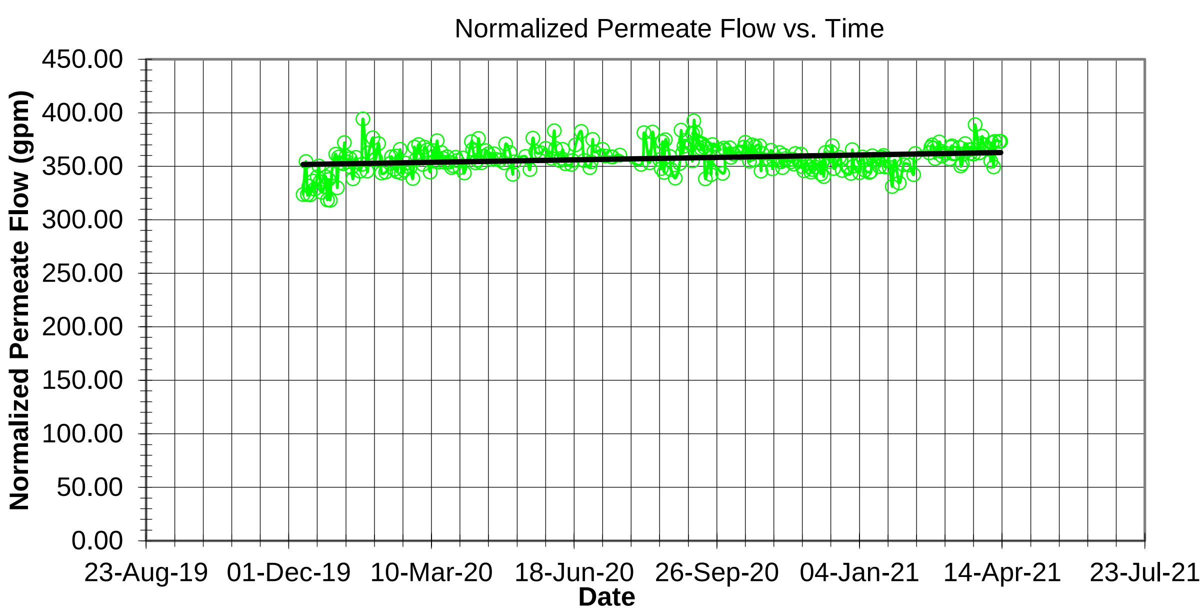


Figure 6: Normalized permeate flow was very stable after the dosing point of the new antiscalant was moved upstream of the RO feed tank.

The plant is currently in the process of upgrading its control system making it more flexible and operator friendly. In the next few months, the plant will see the addition of a permeate blending station with raw groundwater, CIP chemical storage area improvements, post-treatment chemicals for corrosion control, and other items to automate the plant. As part of this project, the addition of variable frequency drives to the existing wells and high-pressure pumps will eliminate the existing RO feed tank.

Conclusion

RO membrane systems treating iron-containing groundwater should not use atmospheric feed tanks. In this case, the iron precipitation issues in the feed tank were fouling the membranes and causing severe surface abrasion. These issues were mitigated by moving the antiscalant dosing point upstream of the feed tank and developing an antiscalant with the capability of inhibiting iron precipitation and dispersing existing precipitates. Moving the dosing point required changes in plumbing and in the controls; this could not be achieved without a concerted effort by all involved parties. The plant has since been operating without any fouling issues.