Case Study: Optimizing Scale Inhibition Costs in Reverse Osmosis Desalination Plants

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Abstract

Over the last few decades, advancements in technology and engineering design have allowed for the construction of reverse osmosis (RO) plants with increased production capacities that could operate at reasonable energy costs. Yet the portion of the operating cost related to consumable scale inhibition chemicals has not changed dramatically due to the disregard by the water treatment community for emerging scale inhibition technologies. The result has been the consumption of enormous quantities of sulfuric acid unnecessarily increasing pretreatment, post-treatment and brine disposal costs.

A water district in suburbs of Los Angeles, California has recently completed the construction of a 265,000 m^3/day MF/RO plant for wastewater reuse. Based on 30 years of experience operating a 19,000 m^3/day MF/R.O. plant, the district took a novel approach to reducing the cost of consumable scale inhibition chemicals. A competitive bid was issued which took into account feed pH in addition to cost and dosage of antiscalant.[1]

The feed pH was used to calculate an acid dosage rate and the annual cost of sulfuric acid use for pH reduction. This was then combined with the annual cost of the antiscalant in order to select the most cost effective treatment as offered by the various antiscalant manufacturers participating in the bid. The selected treatment was then piloted for 50 days to verify its performance at the dosage and feed pH claimed by the manufacturer.

Introduction

The pretreatment of large scale RO systems almost always includes chemical dosing for scale prevention. Scaling occurs in the brine stream when soluble salts exceed their saturation limits and precipitate on the membrane surface. The most common scalants are calcium carbonate, calcium fluoride, calcium sulfate, barium sulfate, strontium sulfate and various silica complexes. Iron and manganese can also precipitate out in the brine stream, but are considered to be foulants. In R.O. treatment plants utilizing wastewater as the feed, calcium phosphate scaling is also of concern; however this scalant is often overlooked as it is unlikely to be an issue in brackish or sea water plants and most membrane projection programs do not take it into account.

The chemicals used for control of these scalants and foulants usually consist of a combination of sulfuric acid and an antiscalant. The sulfuric acid is used to reduce the pH throughout the system to maintain solubility of calcium carbonate, calcium phosphate, iron and manganese. The antiscalants are employed to control the remaining scalants. The more advanced antiscalants on the market are capable of controlling all the abovementioned scalants and foulants at higher pH levels than possible with their predecessors, thereby reducing or completely eliminating the need for acid dosing.

There are a variety of different antiscalants on the market, many with limitations due to their chemical structures. For example, polyacrylate and polymaleic based antiscalants used by many manufacturers will often get deactivated in the presence of as little as 0.5 ppm iron, losing their scale inhibition qualities and precipitating on the membrane as an organic gel-like foulant. Phosphinocarboxylate based antiscalants have similar weaknesses unless used in combination with high enough dosages of acid to convert all iron into its soluble form. Most manufacturers will not advertise the limitations of their own products leaving the end-user with the frustrating task of cleaning their membranes on a frequent basis. This is further augmented by the fact that many manufacturers recommend lower dosages to be competitive even when the water chemistry will not allow for the product to successfully inhibit scale formation at that dosage.

Membrane scaling can have many negative cost impacts on an R.O. plant. The increased feed pressure required to maintain permeate production can result in tremendous energy costs, especially in the case of a high capacity 265,000 m^3/day RO plant. This is in addition to the obvious cost of man-hours, chemicals and loss of production during membrane cleaning.

In order to substantiate the claims of the lowest bidder, the water district's bid included a pilot testing phase for a period of 30 days. The pilot unit consisted of 7 – 4" elements, configured in a 2:1 array and operated at 87% recovery and 12 gfd permeate flux.[2]

Dosage Rates and Required Feed pH using Various Antiscalants

All the well known antiscalant manufacturers participated in the antiscalant bid. The most cost effective treatment was determined to be A-102 Plus, despite the fact that the dosage was higher than the other products.

The annual cost savings in acid consumption alone were determined to be more than $1.1M for the full scale 265,000 m^3/day RO plant based on the cost of sulfuric acid in 2005 when the bid was opened. When the plant finally started operating full time in 2008, the savings in sulfuric acid were calculated to be $8.4M annually. The fluctuating commodity market makes reliance on sulfuric acid very risky and in this case costly. The antiscalant dosage of the A-102 Plus was somewhat higher than some of the dosages claimed by the other antiscalant manufacturers in the bid; nevertheless, the cost of the dosage differential was negligible when compared to the whopping $8.4M/year savings in sulfuric acid costs.

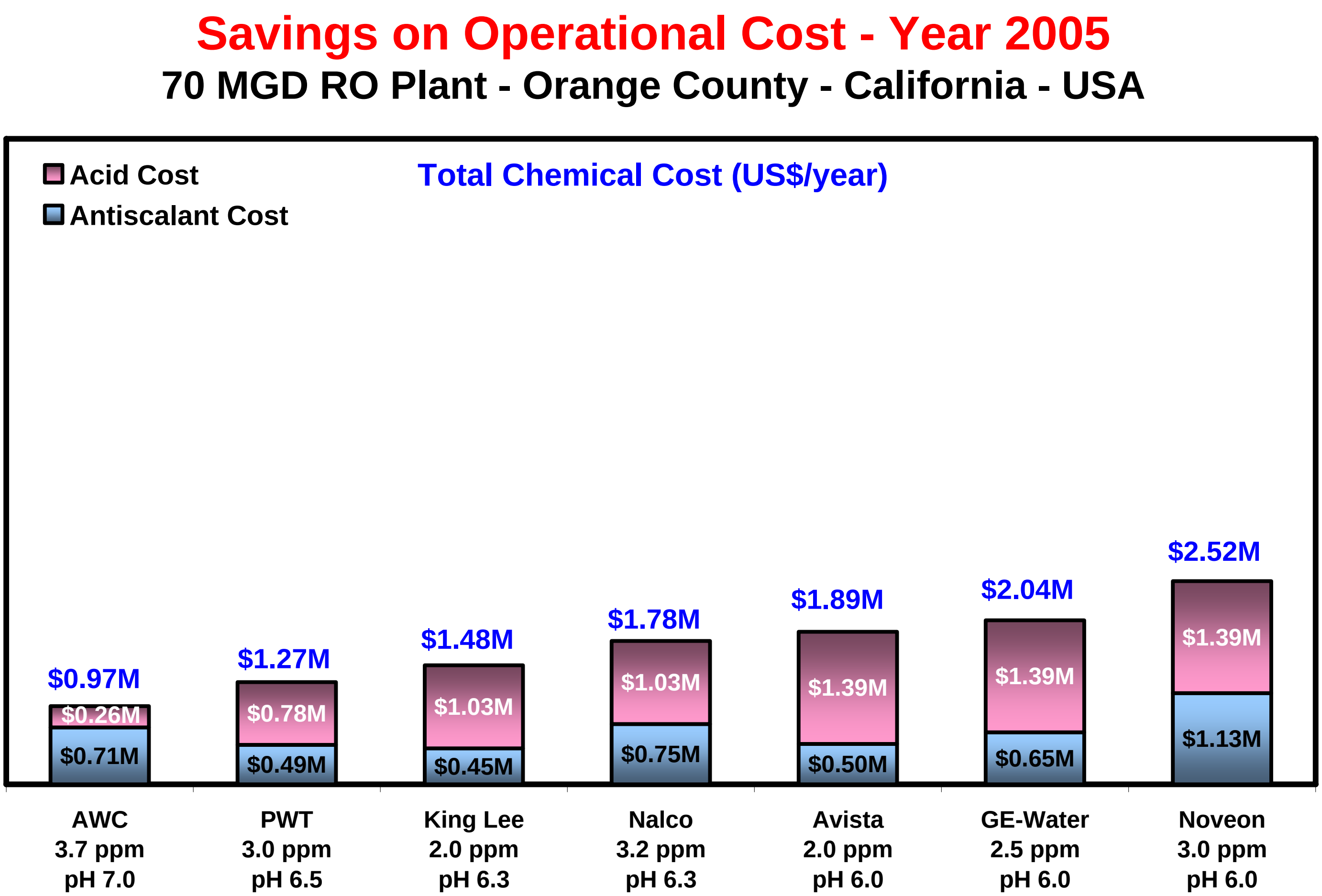

Figure 1-A **<u>Comparison of total annual cost of scale inhibition using pricing and dosages of the participating bidders and the prior supplier.</u>** **Based on cost of sulfuric acid in 2005, total savings using AWC were in excess of $1.5M/yr**

Antiscalant	Noveon AF-1025 (Product used prior to bid)	AWC A-102 Plus (Product A)	PWT Spectraguard (Product B)	King Lee Pretreat Plus 100 (Product C)	Nalco PC-1850 (Product D)	Avista Vitec 3000 (Product E)	GE Betz MSI 310 (Product F)
Dosage (mg/L)	3.0	3.7	3.0	2.0	3.2	2.0	2.5
Feed pH	6.0	7.0	6.5	6.3	6.3	6.0	6.0
Acid Cost/Year ($/yr)	$1.39M	$0.97M	$1.27M	$1.48M	$1.78M	$1.39M	$1.39M

Table 1: Calculated annual cost of acid in year 2005 for 265,000 m^3/day MF/RO plant at feed pH recommended by antiscalant manufacturers for bid submittal.

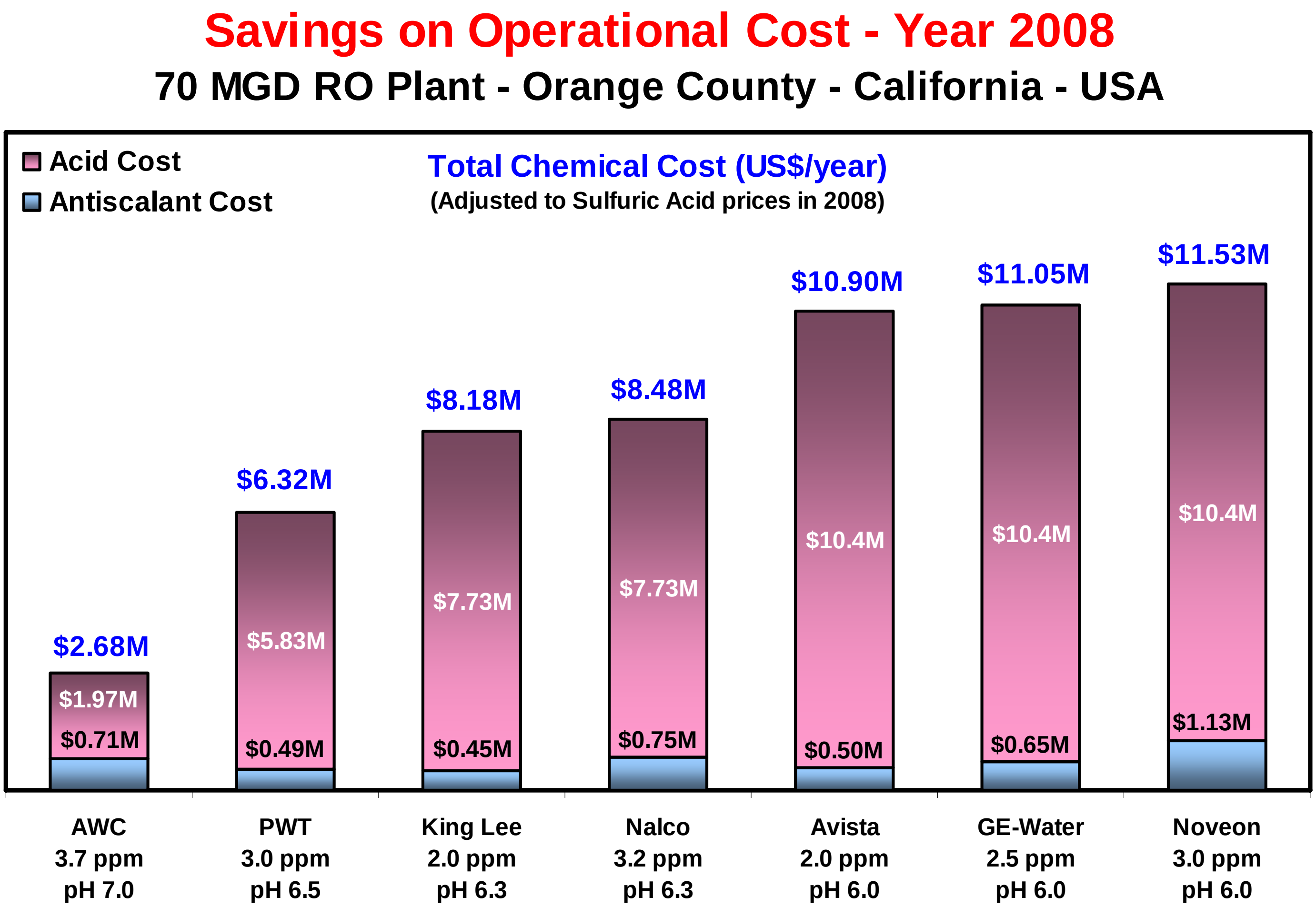

Figure 1-B **Comparison of total annual cost of scale inhibition using pricing and dosages of the participating bidders and the prior supplier.** **Based on cost of sulfuric acid in 2008, total savings using AWC were in excess of $8.8M/yr**

Antiscalant	**Noveon AF-1025 (Product used prior to bid)**	**AWC A-102 Plus (Product A)**	**PWT Spectraguard (Product B)**	**King Lee Pretreat Plus 100 (Product C)**	**Nalco PC-1850 (Product D)**	**Avista Vitec 3000 (Product E)**	**GE Betz MSI 310 (Product F)**
Dosage (mg/L)	3.0	3.7	3.0	2.0	3.2	2.0	2.5
Feed pH	6.0	7.0	6.5	6.3	6.3	6.0	6.0
Acid Cost/Year ($/yr)	$10.40M	$1.97M	$5.83M	$7.73M	$7.73M	$10.40M	$10.40M

Table 1: Calculated annual cost of acid in year 2008 for 265,000 m^3/day MF/RO plant at feed pH recommended by antiscalant manufacturers for bid submittal.

RO FEEDWATER QUALITY *

Constituent	Units	as	Range of Data Min.	Max.	Mean
Ca	mg/l	Ca	60.3	89.4	76.5
Mg	mg/l	Mg	18.3	27.0	24.1
Na	mg/l	Na	189	246	219.3
K	mg/l	K	16.6	20.5	18.7
HCO_3	mg/l	$CaCO_3$	305	453	379
SO_4	mg/l	SO_4	76.2	265	154
Cl	mg/l	CL	180	225	212.2
PO_4-P	mg/l	P	0.2	2.3	0.45
TDS	mg/l	-----	974	1053	1011.8
pH	units	-----	7.9	8.0	8.0
Total Hardness	mg/l	$CaCO_3$	249	326	290.2
Org-N	mg/l	N	0.31	1.35	0.91
NH_3-N	mg/l	N	26.3	29.5	28.0
NO_3-N	mg/l	N	0.28	0.62	0.418
TOC	mg/l	-----	11.2	14.7	12.5
B	mg/l	B	0.41	0.46	0.44
F	mg/l	F	--	--	0.9
Fe	μg/l	Fe	149	207	178.2
Mn	μg/l	Mn	40.7	72	55.0
Silica	mg/l	SiO_2	18.3	26.8	23.7
Temperature	Deg F	--	71	86	80

* BEFORE pH adjustment with Sulfuric Acid

Figure 2: Feed Water Quality at the MF/ RO Waste Water Treatment Plant

Pilot Test Results

Following the bid results, A-102 Plus was piloted by the water district for 30 days. At 87% recovery, the brine stream was anticipated to have a silica concentration as high as 206 mg/L, a phosphate concentration as high as 45 mg/L and an LSI of 2.60 (at pH=7.0). After the successful completion of the 30 day test and award of the contract, the water district decided to continue piloting for an additional 20 days. A-102 Plus was then piloted on the 19,000 m^3/day Phase 1 plant for an additional 50 days to confirm that it would continue to perform on a full scale level.

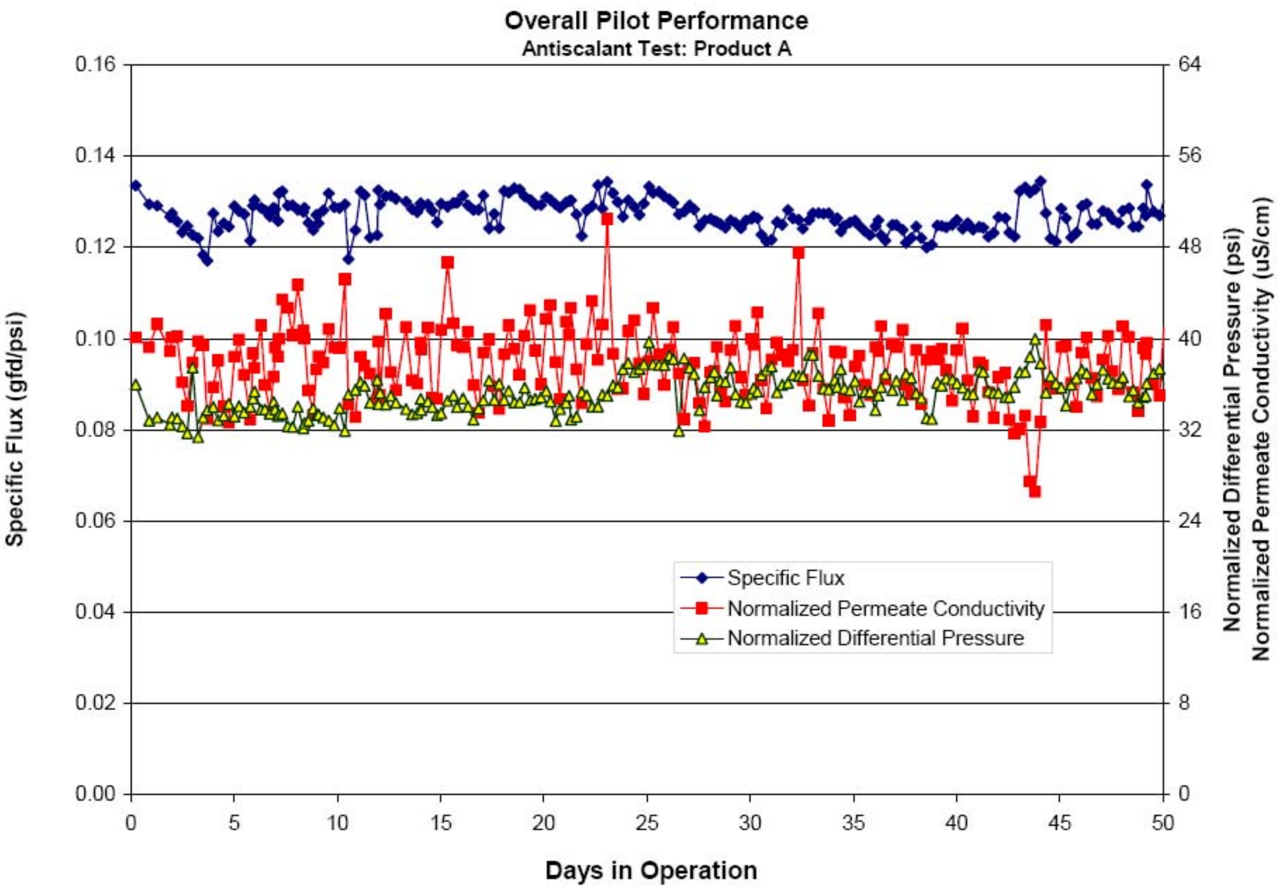

Figure 3. Overall Performance of R.O. Pilot System During Test of A-102 Plus[1]

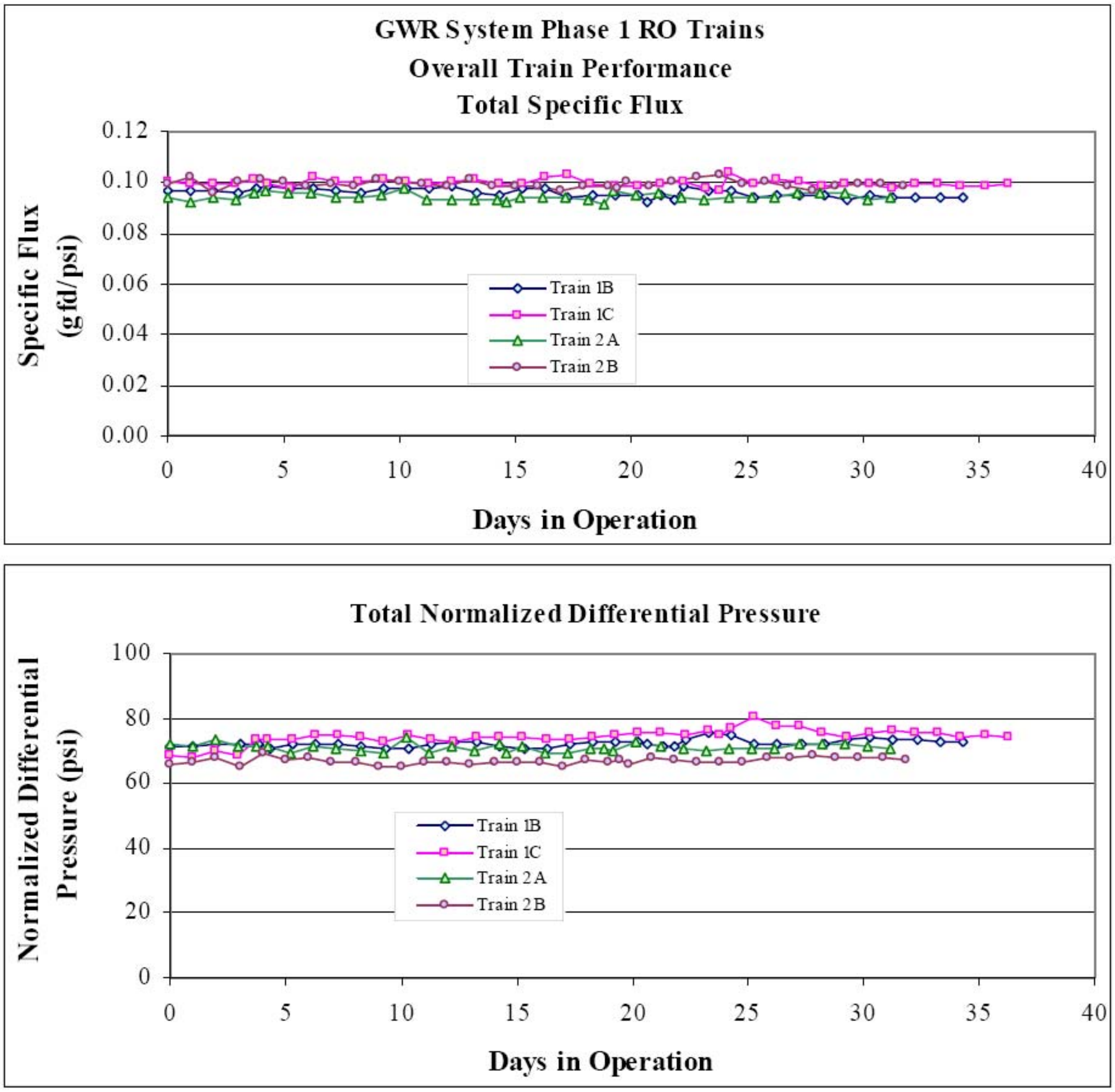

Figure 4: Performance of 19,000 m^3/day Phase 1 RO During Test of A-102 Plus[1]

Conclusion

It is evident that an antiscalant should not be evaluated based on its cost and dosage alone. In this case the antiscalant portion of the annual cost was not the lowest, however A-102 Plus still prevailed as the most cost effective solution due to the higher pH set point.

The operating cost associated with acid dosing is often neglected due to the notion that acid is a lower cost alternative to antiscalant. This misleading assessment stems from the fact that sulfuric acid is a fraction of the cost of antiscalant on a unit basis. However, when taking into consideration that the average R.O. plant doses anywhere from 50 – 350 ppm sulfuric acid in order to adjust the pH, it quickly becomes very apparent that this is not a low cost method for scale inhibition. In this particular case, the waste water treatment plant reduced their acid related costs by more than $1.1M/year by raising their feed pH from 6.0 to 7.0. The savings in adjusting the permeate pH were not taken into account for the purposes of this study, however they would be substantial.

The antiscalant manufacturer should supply a dosage projection showing the recommended dosage rate of the antiscalant as well as the recommended pH set point for the feed water. Since projections are based on theoretical values, these recommendations should be verified by conducting a pilot test. Ultimately, when evaluating operational scale inhibition costs, acid dosing procedures should be reviewed carefully. The price of antiscalant should not be considered as an individual component, but rather assessed as part of an overall expense.

References

1. Owens, E., Dunivin, W. and Knoell, T., *Employing a New Methodology for Antiscalant Procurement for Reverse Osmosis Membrane Facilities*, Waterreuse Symposium presented in Hollywood, California.

2. Knoell, Tom and Owens Eric, *A New Method in the Procurement of R.O. Antiscalant Chemicals,* Ultrapure Water, Vol.23, No.6, September 2006, Pg.20 - 28