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REMEDIATING BIOFOULING OF REVERSE OSMOSIS MEMBRANES (U)

by

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SUMMARY

Several potential additives and the use of influent pH adjustment were examined to remediate the biofouling problem of the ETF reverse osmosis (RO) system. Tests were conducted with simulated RO feed containing salt, metal hydroxides and bacteria. The addition of sodium hexametaphosphate (SHMP), sodium bisulfite, and adjusting the influent pH to 3 were each successful in reducing the RO biofouling. Little or no benefit was found from the use of a biofilm remover (Filmtec Alkaline Cleaner) or the use of surfactants (Surfynol or sodium lauryl sulfate). In addition, Surfynol use resulted in irreversible fouling and necessitated membrane replacement.

At the water recoveries used in the ETF (>90%), sodium bisulfite addition resulted in the recovery of 70-90% of the flux and almost complete restoration of the DF to prefouled conditions. SHMP also produced complete restoration of the DF but flux recovery was somewhat less than with bisulfite. Adjustment of the influent pH to 3 recovered approximately 50% of the lost water flux but improved the DF over the initial prefouled conditions.

Based on the bench-scale tests completed, IWT would recommend that sodium bisulfite addition be tested at the ETF. This testing would involve optimizing the amount of bisulfite required. In addition, it is recommended that the addition of SHMP or influent pH adjustment be evaluated since the relative differences in lab-scale tests were small and scale-up effects could be present. The ETF operating permit allows each to be added.

INTRODUCTION

Biofouling of the ETF RO membranes [e.g., Siler (1991a), (1991b)] has been confirmed and quantified under ideal laboratory conditions. Since chemically cleaning the membranes has been ineffective at restoring and maintaining RO performance, a solution was needed to reduce the adsorption and fouling potential of the bacteria in the ETF feed.

Several pretreatment chemistry changes are available to the membrane process. Simple feed pH adjustment often corrects a difficult processing problem. It was postulated that the colloidal metals/bacteria complex could be altered by dissolving the colloids at low pH or modifying them at high pH. Changes in the metals/bacteria matrix should reduce the fouling potential.

The use of antiscalents, such as sodium hexametaphosphate (SHMP), could possibly reduce the adsorption potential of bacteria on the membrane surface. Antiscalents work by two mechanisms: 1) by providing a lubricant coating for the membrane surface and 2) by forming a complex with the species in solution. These two mechanisms work to produce larger, less adhering molecules in solution, which should improve RO performance.

Another potential method is to add sodium bisulfite to the membrane feed. Sodium bisulfite is well-known to reduce biofouling in DuPont Permasep™ membrane applications [see Applegate (1987)]. The DuPont membrane has a similar structure to the Filmtec membranes in use at the ETF, and thus the potential for enhanced performance was postulated.

EXPERIMENTAL PROCEDURE

The basic experimental procedure was outlined in report #WSRC-RP-91-431. Detailed operating instructions can be found in TNX operating procedure #679T90039.

The bisulfite experiment required the neutralization of the solution after the bisulfite was added. Addition of bisulfite resulted in the solution pH dropping to about 3, which results in artificially high solution conductivities, particularly for permeate samples. The other feed additives did not require any further solution modification.

RESULTS AND DISCUSSION

Sodium Bisulfite Addition

A comparison of the successful remediation strategies is given in Figures 1-3. The addition of 500 mg/l sodium bisulfite resulted in 90% flux restoration at lower water recoveries and 70-80% at high water recoveries. Processing a pure salt solution subsequent to the bisulfite test showed that there was no permanent flux loss. All of the lost DF was restored (Figure 2) when bisulfite was added.

The routine use of 500 mg/l sodium bisulfite would be impractical from a reagent standpoint. This amount was chosen simply to determine whether this reagent would benefit performance.

Additional testing at SRL or at the ETF to optimize the amount would be the next logical step.

Sodium Hexametaphosphate (SHMP) Addition

The use of SHMP to remediate the biofouling resulted in about 50% improvement in the water flux (Figure 1). About 5-8% flux loss remained after the simulant was replaced with a pure salt solution. Here again complete restoration of the lost DF occurred (Figure 2).

This small flux loss could be restored by cleaning the membrane with 0.1% NaOH (pH=12) at 200 psi and 35 °C. Also, any flux losses that occur while processing bacteria can be offset by increasing the feed pressure.

Feed pH Adjustment

The feed pH was reduced to 3 to determine whether performance would improve as the metals were redissolved into solution. The flux results obtained were very similar to those noted for SHMP (Figure 1). Approximately 10-12% flux loss remained when a pure salt solution was subsequently processed. This would mean that slight increases in the RO feed pressure would be required to maintain throughput. The flux could be restored by cleaning the membrane with NaOH.

The DF results are shown in Figure 3. These results were plotted on a separate graph, because these tests were performed on a different Filmtec membrane module which had lower intrinsic salt rejection (e.g., R=98.5% as compared to 99.2%). The DF values will be substantially different, because DF is related to salt rejection by

$$DF = \frac{1}{1 - R} \tag{1}$$

and thus small changes in the salt rejection will be magnified in the computation of DF as the salt rejection values approach 100%. The positive aspect of this test was higher DF values were obtained at higher water recoveries, and that little if any DF loss remained when a pure salt solution was subsequently processed.

Adjusting the feed pH to 11 was also tested. The flux remained high after bacteria were added to the solution. However, little improvement in the observed DFs was noted.

Other Additives

Little improvement was noted when Surfynol, sodium lauryl sulfate, or Filmtec Alkaline Cleaner were tested at biofouling remediation.

In fact, the use of Surfynol resulted in irreversible flux and DF loss and necessitated membrane change. Both sodium lauryl sulfate and the Filmtec cleaner resulted in about 20-30% DF loss in a pure salt solution following the bacteria testing. Also, the Filmtec cleaner resulted in 10-40% additional flux loss on the pure salt solution. The flux and DF losses that occurred from using the Filmtec cleaner and the sodium lauryl sulfate could be restored via cleaning the membrane with NaOH.

Rating the Various Additives

The best performance occurred when using sodium bisulfite. Very little flux loss occurred, also salt DF was unaffected by the presence of bacteria when bisulfite was used.

Adjusting the feed pH or SHMP addition was not as successful at flux restoration, but salt DF was very good.

All three of these process changes are readily implementable at the ETF, since the permit allows for these changes.

CONCLUSIONS AND RECOMMENDATIONS

Three viable improvements to the biofouling problem with the ETF RO system have been developed. Addition of sodium bisulfite resulted in the best overall membrane performance. However, the performance enhancements noted for SHMP and pH adjustment also look very promising.

Eventual testing of all three process changes is recommended due to the small-scale nature of the tests discussed heretofore, and possible scale up/fresh feed questions are difficult to answer. The ETF operating permit includes SHMP and bisulfite addition, thus the implementation should be straightforward. The potential performance improvements could restore the ETF RO system to its design capacity.

QUALITY ASSURANCE

The work described in this report was performed according to the guidelines in the SRS QA manual. The data collected during these tests were recorded in laboratory notebook #WSRC-NB-90-257.

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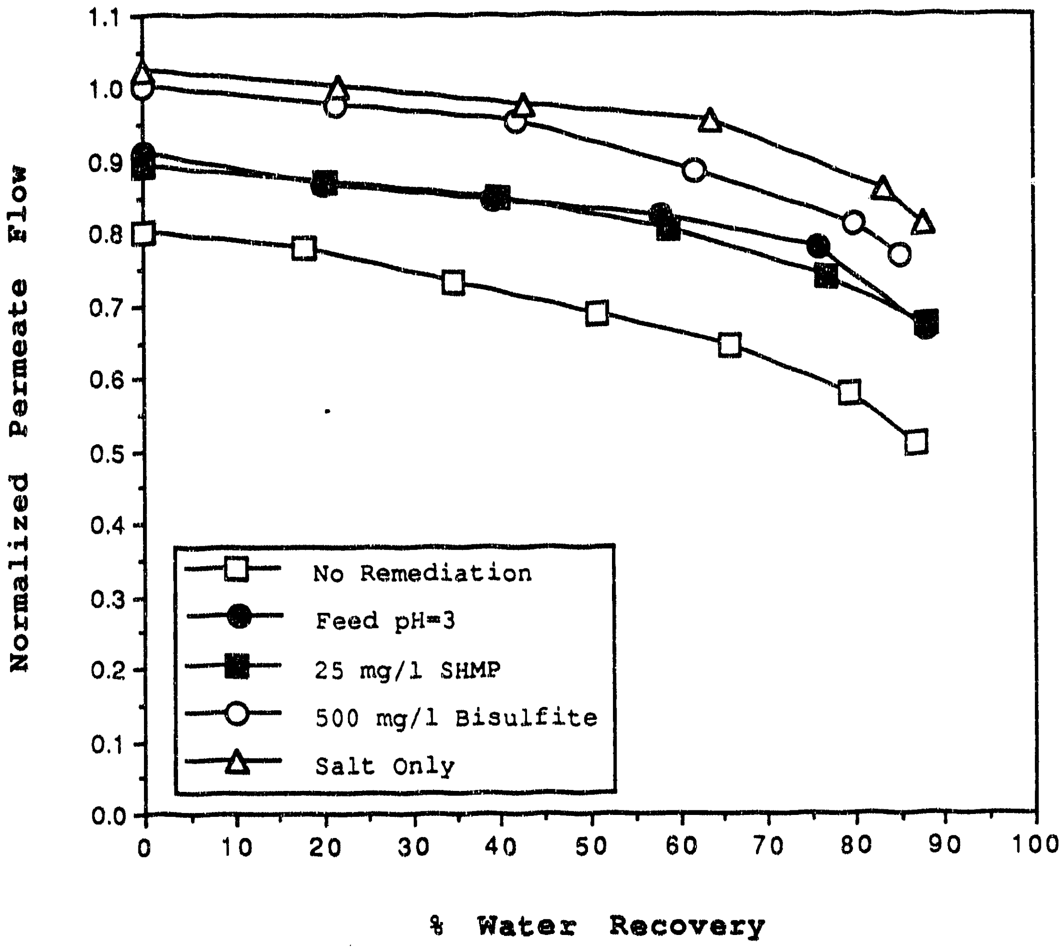

Figure 1. Remediation of Flux Losses due to Biofouling.

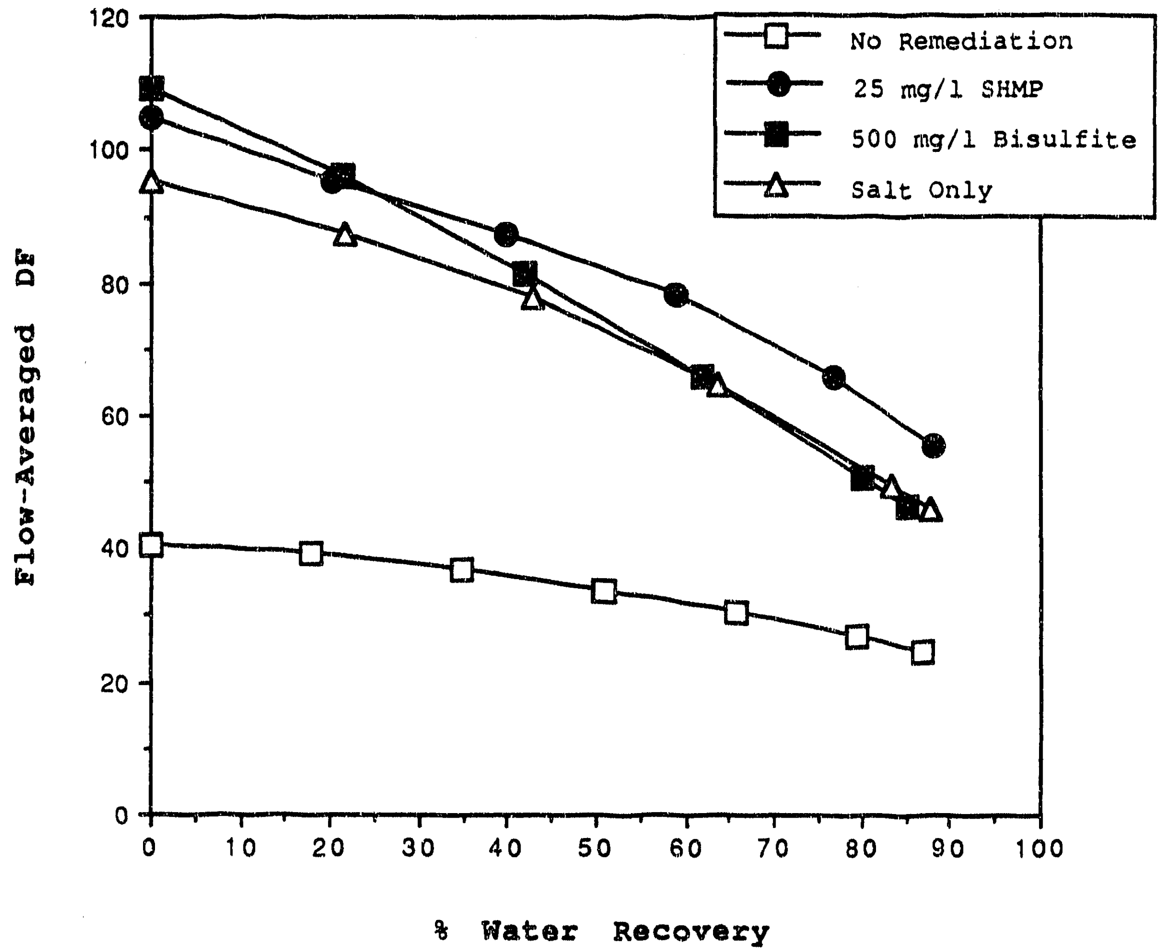

Figure 2. Remediation of DF Losses Due to Biofouling.

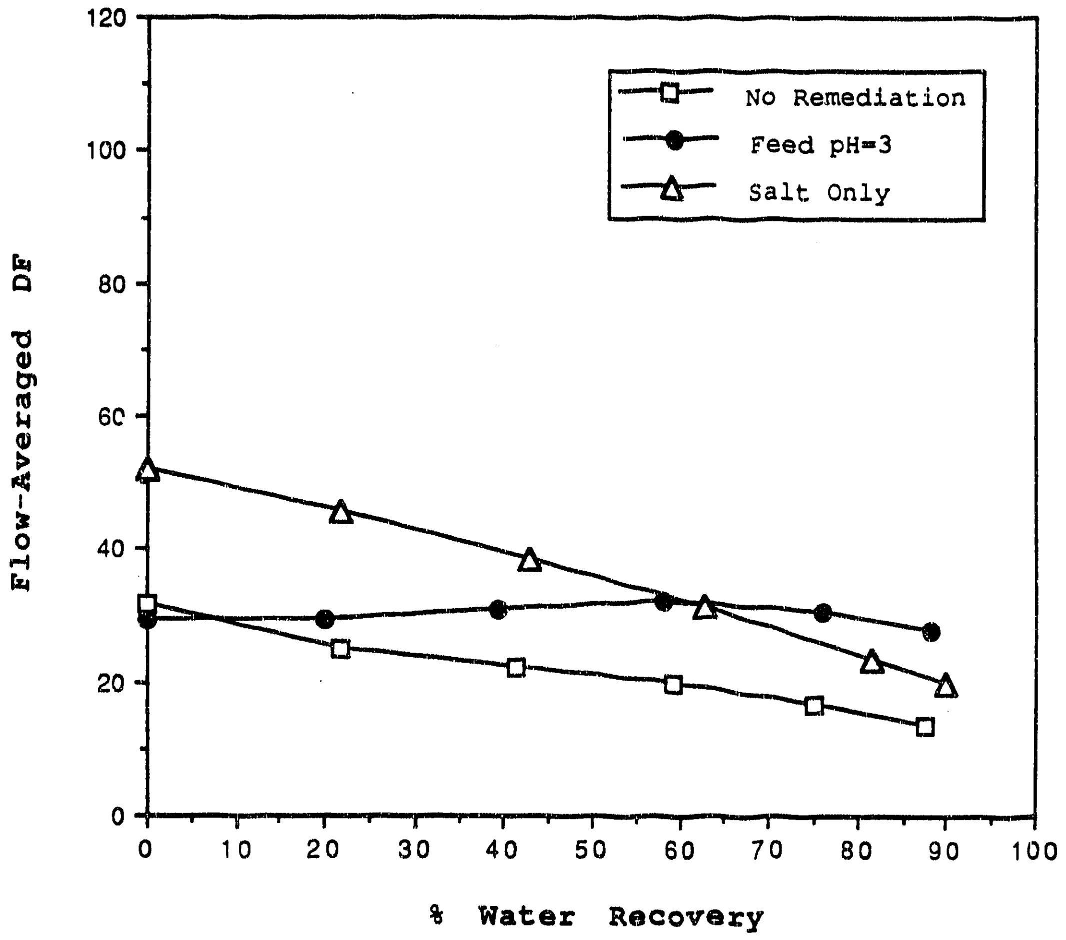

Figure 3. Remediation of DF Losses by Feed pH Adjustments.

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