Prevention of precipitation fouling in NF/RO by reverse flow operation

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Introduction

Precipitation of sparingly soluble salts is one of the main factors limiting the recovery in reverse osmosis of brackish water sources. Recoveries can be increased and antiscalant usage reduced or curtailed by applying flow reversal to RO trains. Flow reversal works by changing the place of the entrance and exit of the feed before the induction time of the supersaturated solution along the membrane wall runs out and precipitation occurs. Reversing the flow before the induction time of the system is reached replaces the supersaturated brine at the exit with the unsaturated feed and thus “zeroes the induction clock”.

Experimental

Reversing the flow in a series of RO elements was simulated in laboratory experiments by running a flat sheet test cell with two solutions, one supersaturated and one undersaturated, that were periodically switched. The supersaturated solution simulated the concentrate stream at the exit of an RO pressure vessel. The undersaturated solution simulated the feed stream into an RO pressure vessel. In the lab experiments, the flat sheet test cell was run for 30-90 minutes on the supersaturated solution and then 10 minutes on the undersaturated solution. The feasibility of flow reversal was successfully demonstrated on supersaturated calcium sulfate solution (saturation index ~ 180%) formed from calcium chloride and sodium sulfate. In another experiment, feasibility was demonstrated with 300 mg/L SiO_2 in the presence of 300 mg/L $CaCl_2$ and 125 mg/L $MgCl_2$ as the supersaturated solution.

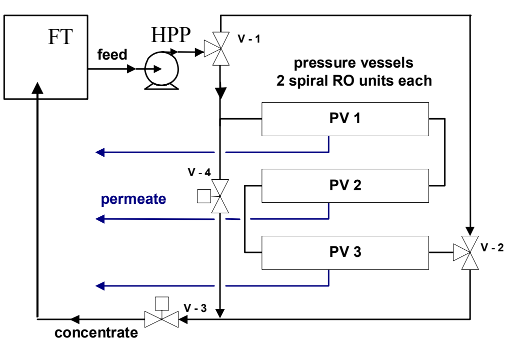


Figure 1: Pilot flow reversal scheme. In forward flow, valves v-1 and v-2 are in up position and valve v-4 is closed. In reverse flow these valves are in the opposite position.

In order to carry out actual pilot testing of the flow reversal technique, an automatic flow switching manifold was constructed and used with a 6 element RO train (see figure 1). The mechanical stability of spiral wound elements in this system were evaluated by frequent repeated flow reversals. It was run continuously for 10 days with switching every 10 minutes – equivalent of 3 months operation with flow reversal every two hours. The test solution was 1500 ppm NaCl and rejection was maintained at >99.5% for the entire test time. This demonstrates that the method of flow reversal was not deleterious to the element seals or performance.

The pilot unit was tested on solutions of 7.5 mM and 10 mM calcium sulfate in the feed at recoveries ranging from 67 – 82% leading to supersaturation indices as high as 3.5-5.4 at the membrane wall at the concentrate end. It was also tested on calcium carbonate solutions with an LSI of 1.0.

Results

Lab Results

In separate lab experiments with supersaturated calcium sulfate and silica, the unit was run for three times the induction times by periodically switching to undersaturated solutions for 10 minutes every 30-90 minutes.

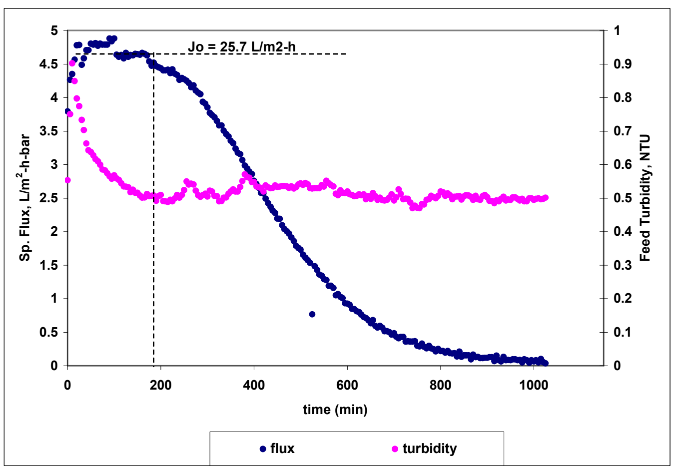


Figure 2: Induction time experiment with 0.03 M CaSO4 and 0.06 M NaCl. P=10 bar, Q=100 L/m (0.7 m/s).

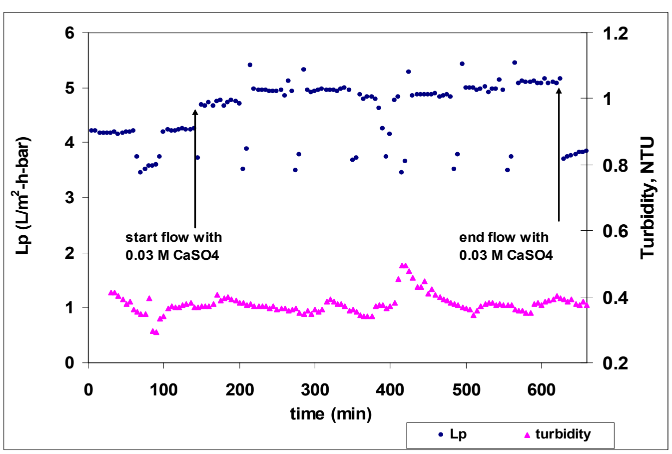


Figure 3: Switch experiment, Run conditions as in Figure 2, every 60 minutes, solution of 0.01 M CaSO4 and 0.02 M NaCl run through membrane test cell for 10 minutes

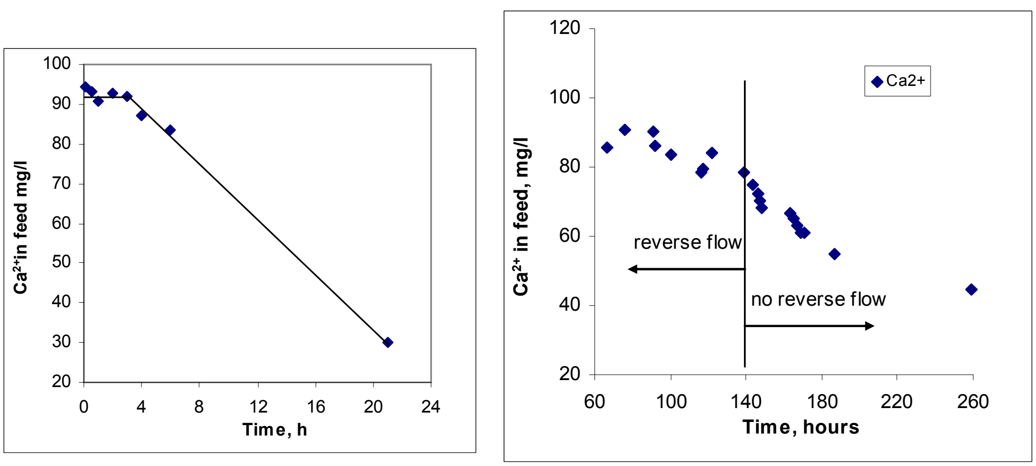
The effect with calcium sulfate is illustrated in figures 2 and 3 where a solution of 0.03 M of calcium sulfate and 0.06 M NaCl were used as the scaling solution. As can be seen in figure 2a, the induction time was 180 minutes. When the solution was switched with 0.01 M calcium sulfate and 0.02 M NaCl for 10 minutes, the flux was maintained stable for an entire run of 480 minutes.

In experiments with 300 mg/L of silica, the flux declined by 32% in 5 hours after an induction time of 170 minutes. When the supersaturated solutions were switched to an undersaturated solution of silica (50 mg/L as SiO_2 and correspondingly lower $CaCl_2$ and $MgCl_2$ concentrations) for 10 minutes, after every 90 minutes of operation, the flux showed no sudden decline and after 8 hours only 9% of the original flux had been lost.

<u>Pilot Results</u>

In calcium sulfate experiments on the pilot unit the induction times ranged from 18 hours (at 65-72% recovery and bulk concentrate saturation index of 180%) to 0-1.5 hours (at 80-82% recovery and a concentrate saturation index of 257% and wall saturation index of 540% (concentrate flow rate was only ~3 LPM in 2.5 inch spiral element). In the experiment with 80-82% recovery the specific flux declined by more than 25%. On applying reverse flow every half hour when the unit was run at 80-82% recovery, the membrane was kept free of scaling for the entire18+ hours of the experiment.

With a feed nearly saturated with calcium carbonate (LSI= -0.04), the induction time for running the pilot with 70% recovery (concentrate LSI = 1.51) was 4 hours (see Fig. 4a). When running with reverse flow every hour, the system showed little sign of precipitation after 80 hours of continuous running (see Fig. 4b) as illustrated by calcium levels.



a) b)

Figure 4: Pilot RO runs on feed solution slightly undersaturated with respect to $CaCO_3$ (LSI= -0.04) and 70% recovery (concentrate LSI = 1.51) . a) without flow reversal b) with flow reversal