Barium sulfate scaling of Anion exchange membranes using Donnan dialysis

The operation of high recovery electrodialysis in treating brackish water or RO concentrate is often limited by formation of mineral deposits on the concentrate side of the membranes. Typical sparingly soluble minerals that can cause such problems are calcium sulfate, barium sulfate, and silica. In previous studies we have examined gypsum (calcium sulfate dehydrate) scaling by Donnan dialysis [1] and electrodialysis [2]. In the present study we examined barium sulfate which is far less soluble than gypsum, and observed its effect on the membrane properties and the locus of the scaling.

Donnan dialysis was used for this study as it afforded the in-situ examination of scaling on the membrane. The setup for the experiment is shown in Figure 1. In the Donnan dialysis study, two types of anion exchange membranes are used, homogeneous AMV and heterogeneous MA-40. A high concentration chloride solution (1.0 N) was placed in the receiving compartment and a more dilute sodium sulfate solution (0.02 N) was placed on the feed compartment. The sodium chloride solution was spiked with barium chloride (10, 50 and 200 mg/L) for the scaling studies. This is in great contrast to the calcium sulfate experiments where Ca^{2+}, the scaling cation in the receiving compartment was used at 0.1 – 0.5 N. The anions were exchanged between the two solutions driving sulfate into the receiving compartment where it can precipitate as barium sulfate solubility is exceeded.

Typical scaling runs are shown in Figure 2. One can see that sulfate flux dropped more quickly (as shown from deviation from the linear dependence of sulfate transport vs time) for the homogeneous membrane AMV as opposed to the heterogeneous membrane MA-40. This is exactly the opposite of the finding for the behavior of gypsum with these two membranes. Examination of the surface (Figure 3) shows that both homogeneous and heterogeneous membranes showed extensive scaling on the surface and the number of crystal growth sites and their individual size increased significantly during the experiment. This is in contrast to gypsum which did not show significant surface scaling on the heterogeneous membrane MA-40. Rather, gypsum scaling of MA-40 was internal because of its reduced permselectivity in presence of high concentration calcium chloride [1]. The two phenomena can be related. Since surface deposition was significant for both membranes, the induction time will be dictated by the barium sulfate saturation index at the membrane surface for both membranes. This in turn will be greatest for the membrane with the highest sulfate flux causing greater surface concentration polarization. Indeed, sulfate flux for the AMV membrane was three times higher than that of the sulfate flux for the MA-40 membrane run with the same solutions.

Further study is now being planned to see if these trends continue under electrodialysis operation.

References:

1. Meital Asraf-Snir, Jack Gilron, Yoram Oren. "Gypsum Scaling on Anion Exchange Membranes during Donnan Exchange", J. Membrane Science, Volume 455, 1 April 2014, Pages 384–391
2. Meital Asraf-Snir, Jack Gilron, Yoram Oren. "Gypsum Scaling on Anion Exchange Membranes in Electrodialysis", J. Membrane Science, DOI: 10.1016/j.memsci.2016.07.013, July 2016.

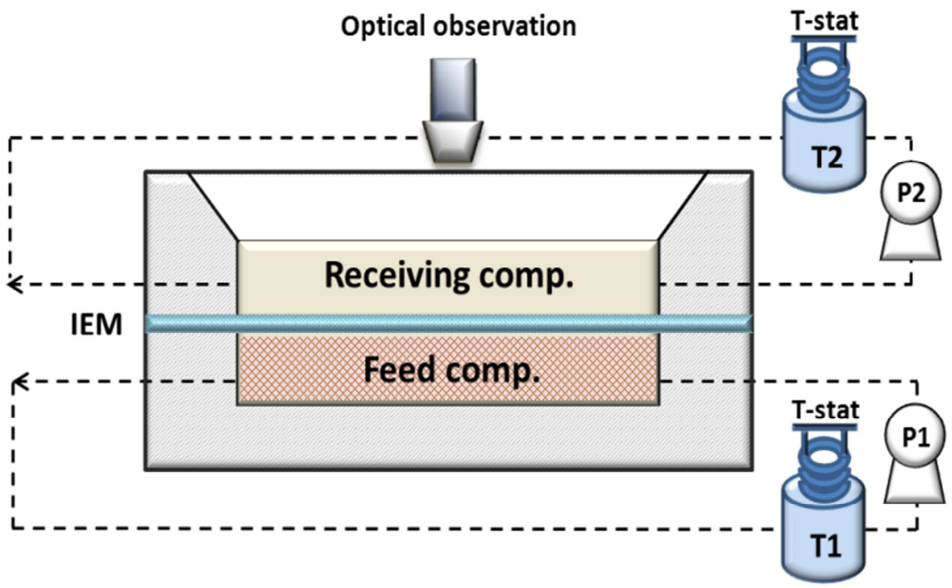


Figure 1: Setup for Donnan dialysis experiment with sodium chloride (0.1 N) in the receiving compartment and sodium sulfate in the feed compartment. IEM was an anion exchange membrane.

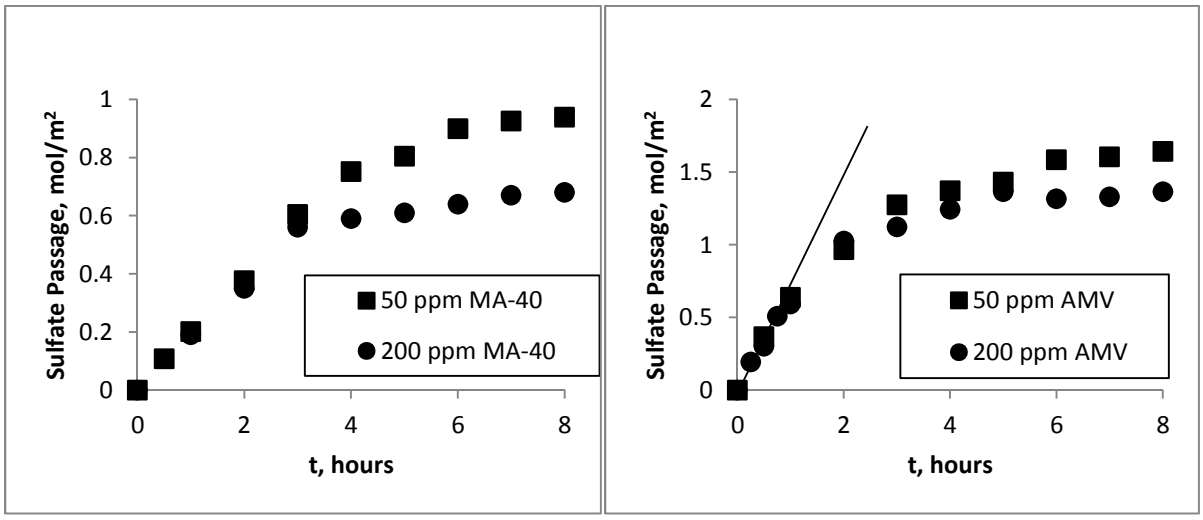


Figure 2: Sulfate passage through anion exchange membrane in Donnan dialysis with barium ion present in the receiving compartment at concentrations listed. Left – MA-40 membrane. Right – AMV membrane.

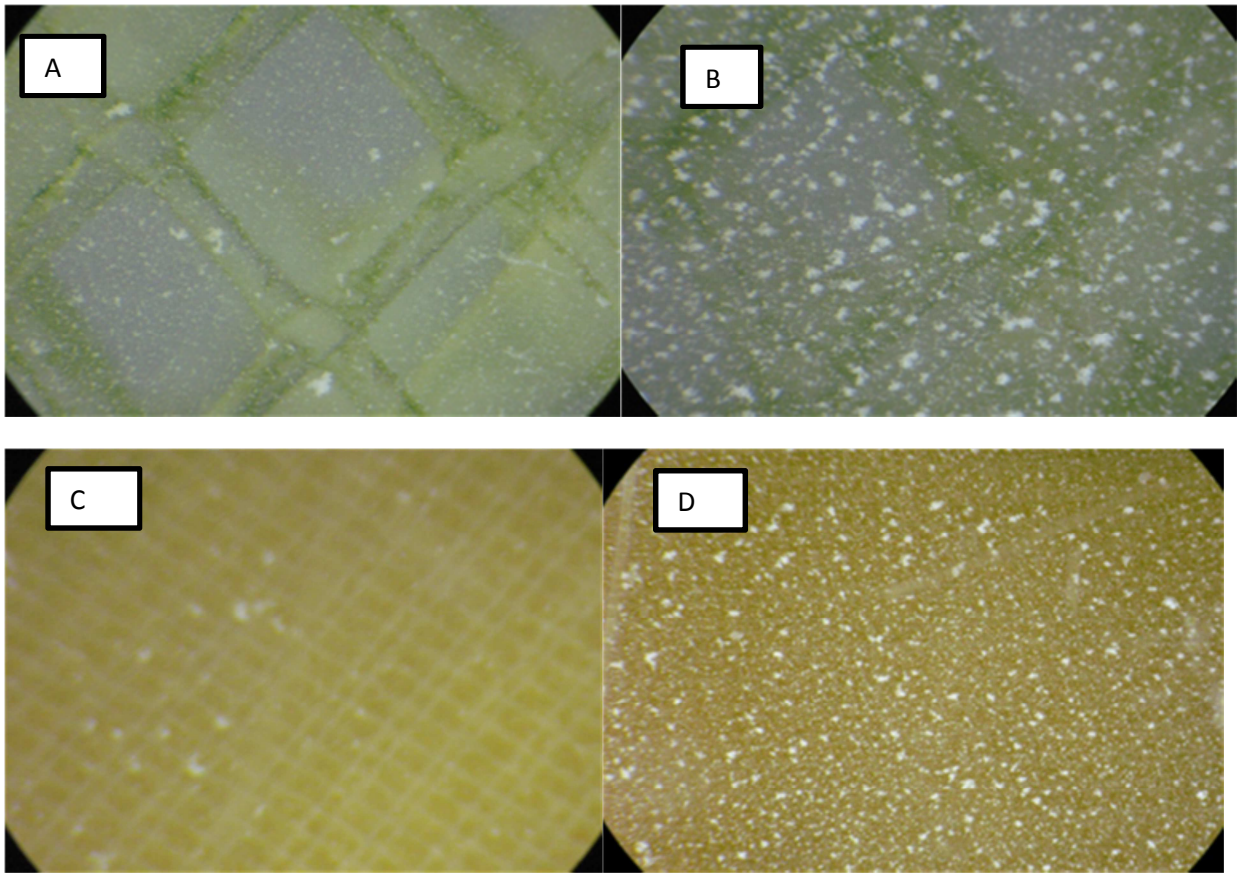


Figure 3: In situ photographs of AMV (A, B) and MA-40 (C,D) membrane during scaling run of Donnan dialysis. Pictures taken at 1 hr (A, C) and 7 hr (B, D) after start of experiment. Receiving compartment contained 50 mg/L of barium ion.