MEMBRANE DISTILLATION FOR TREATING HYDRAULIC FRACTURING PRODUCED WATERS

S. Ranil Wickramasinghe, Ralph E Martin Department of Chemical Engineering, University of Arkansas
swickram@email.uark.edu
Kamyar Sardari, Ralph E Martin Department of Chemical Engineering, University of Arkansas

Key Words: hydraulic fracturing, hydrophobicity, membrane distillation, salinity, water flux

The reuse of wastewater for beneficial uses has become increasingly important in recent years. There is an urgent need to develop innovative and more effective technologies for treatment of wastewaters. Many of these wastewaters such as hydraulic fracturing produced waters, contain very high total dissolved solids (TDS). Treatment of hydraulic fracturing produced waters can be very challenging as not only can they exhibit very high TDS, in excess of 200,000 ppm, they also contain surfactants and small organic compounds. Pressure driven membrane processes such as reverse osmosis are impractical for treating very high salinity wastewaters due to the high osmotic back pressure that must be overcome. Membrane distillation has been proposed as a new unit operation for treatment of very high TDS wastewaters. Vapor pressure is the driving force for water recovery in membrane distillation. An advantages of membrane distillation is the fact that low grade waste heat may be used.

Here we have screened a number of commercially available microporous hydrophobic membranes. We have characterized membrane surface as well as bulk properties. Using bulk membrane properties, we calculate a structural parameter that indicates membranes that display high permeate flux. Next these membranes were challenged with feed streams containing 100,000 ppm (1.7 M) NaCl. The feeds stream was concentrated until breakthrough of the feed liquid into the permeate. Breakthrough occurred when the permeate flux rose rapidly while the conductivity of the permeate increased above 50 mS cm^{-1}. Finally, these membranes were tested with real produced waters. Membranes that enabled the greatest concentration of TDS were selected for testing.

While membrane distillation could be used to concentrate the feed to the solubility limit of the dissolved species present, leakage of feed water through the membrane pores into the distillate often occurs well before this level of water recovery. Leakage occurs due the presence of oil and suspended solids in the feed which can adsorb on the membrane surface. Thus pretreatment of the feed is essential. Here we have investigated the use of electrocoagulation as a pretreatment step for membrane distillation. Suspended solids and oil can be effectively coagulated followed by sedimentation prior to membrane distillation. A laboratory scale electrocoagulation system containing aluminum electrodes was designed, optimized and employed successfully to pretreat the feed.

We have developed a multi-stage membrane distillation system for water recovery from actual hydraulic fracturing produced waters. The multi-stage system was designed due to different on-site requirements for maximum feed TDS and due to different TDS levels in wastewaters from different wells. The feed wastewater was concentrated up to 300,000 ppm without breakthrough. Over 50% water recovery was achieved for actual hydraulic fracturing produced waters from Marcellus shale (Pennsylvania) containing over 100,000 ppm TDS. A simulation based in Matlab R2015a has been developed in order to determine the optimal module dimensions that minimize operating expenses. Figure 1 shows the results of our cost and energy consumption estimations. As can be seen an optimum module exists which minimizes water treatment costs. In this presentation will present experimental and numerical data that indicate module dimensions that minimize operating costs.

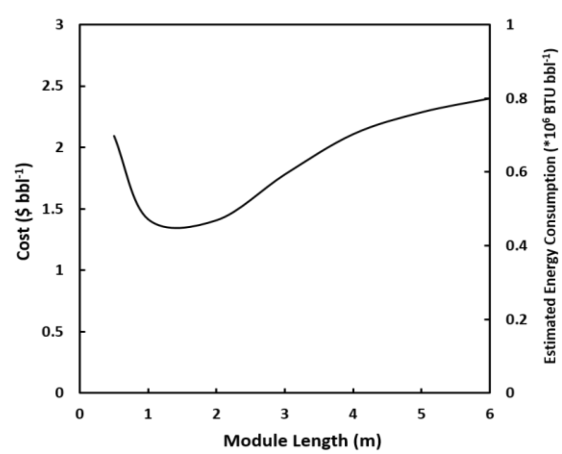

Figure 1 – Cost and energy consumption estimation for multi-stage membrane distillation system