3-1-2013

Disolved CO2 - An Alternative for Cleaning Inorganic Scale from RO Membranes

Erin Partlan
Clemson University

David Ladner
Clemson University

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ERIN PARTLAN, DAVID LADNER
Clemson University

Background

Membrane fouling is a major operational issue in reverse osmosis desalination plants. In particular, plants treating brackish surface waters or groundwater can encounter troublesome inorganic scales that cling to membranes and are difficult to remove.

While many efforts focus on methods to prevent fouling, it is inevitable in a major plant. Here, dissolved CO_2 is proposed as a novel cleaning method to remove scales from inorganically fouled membranes.

Theory

The use of gas for membrane cleaning uses contact between the bubble surface and foulants to shear material from the membrane. Various applications of air flowing over and through membranes have been applied to micro- and ultrafiltration membranes,[1]

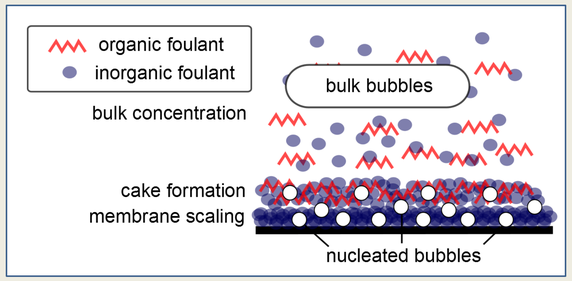

Figure 1: Depiction of gas cleaning mechanism for fouled membranes. Nucleated bubbles form on the membrane and particulates while gas phase bubbles stay in the bulk.

The difference with dissolved CO_2 is that it is not present as gas until it reaches the membrane. The membrane surface provides nucleation sites for gas bubbles to form. This produces bubbles that are smaller and closer to the scales than any type of two-phase air cleaning. This method was shown to be effective in removing biofilms from reverse osmosis membranes by Vitens Water Technology, a company in the Netherlands.[2]

Procedure

(Clean water flux taken after each step)

1. Membrane compaction
2. Reference salt flux
3. Membrane scaling
4. Membrane cleaning

Materials

- CPA2 Hydranautics Low-pressure Reverse Osmosis Membrane
- Plate-and-frame membrane cell (GE SEPA)
- $CaCO_3$ solution: 200 ppm $CaCl_2$, 200 ppm Na_2CO_3, 10 g/L NaCl
- Silicate solution: 400 ppm $CaCl_2$, 300 ppm SiO_2, 10 g/L NaCl

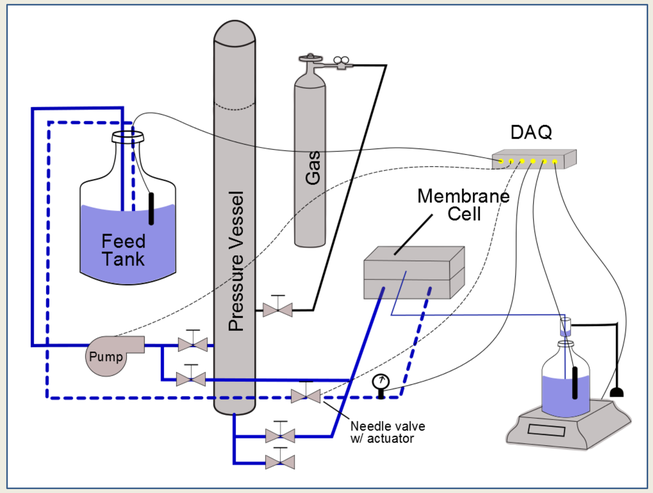

Figure 2: Sketch of bench-scale testing apparatus.

Dissolved CO_2 Cleaning

1. Carbonate water for cleaning solution. Accomplished by bubbling CO_2 into the water column in a vertical pressure vessel. Water volume is 7.5 liters.
2. Open valve to divert water in pressure vessel through membrane cell. Water exits under headspace pressure until empty, a process which takes ***less than 10 minutes***.

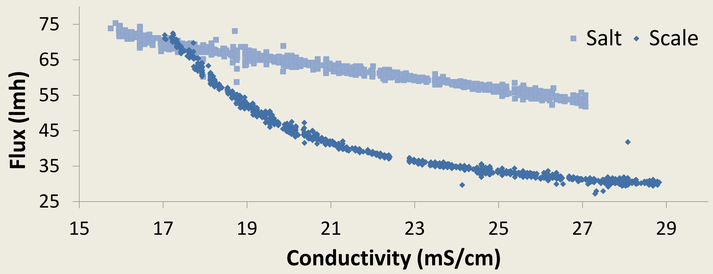

Figure 3: An example of a scaling experiment. NaCl does not produce scales and flux decline is linear with increasing concentration. In scaling solutions, flux decreases both due to increasing concentration and scale formation.

Results

Calcium Carbonate The best cleaning resulted from dissolved CO_2. When cleaned with acid – the standard for removing many types of inorganic scale – similar results were observed. Lastly, clean water provided minimal cleaning.

Calcium Silicates None of the attempted cleaning solutions were able to remove silicate scale. Silica is known to be problematic and typically handled with pretreatment to reduce concentration levels. For cleaning, industrial standards vary between acid and alkaline cleaning solutions.

$CaCO_3$ Scaling and Cleaning Results

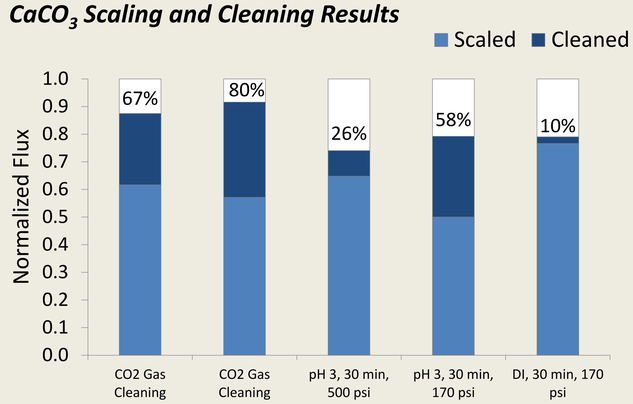

Figure 4: Comparison of cleaning efficiencies for membranes scaled by $CaCO_3$. Cleaning with dissolved CO_2 returned the most flux, followed by acid cleaning.

Silica Scaling and Cleaning Results

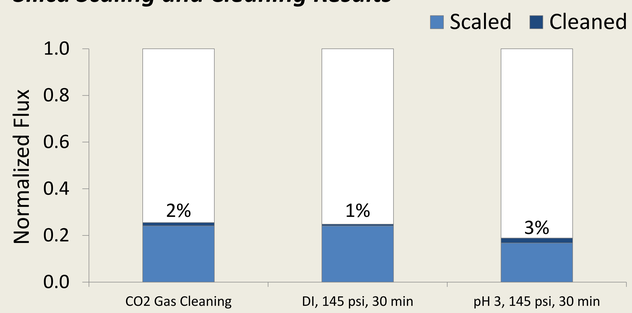

Figure 5: Comparison of cleaning efficiencies for membranes scaled by silicates. None of the attempted cleaning procedures regenerated flux.

Discussion

The fact that dissolved CO_2 works to remove $CaCO_3$ poses questions about the mechanism by which it cleans. The cell is opaque, so visual confirmation of bubble formation is not possible. Other possible methods by which cleaning can occur include pH effects and reactivity. These are especially true for calcium carbonate scale since the cleaning solution drops to pH 4 after carbonation, and the addition of CO_2 itself stimulates changes in carbonate equilibrium. Further work can be done to explore more of these interactions to arrive at the dominant mechanism.

Applications

Green Alternative Dissolved CO_2 can replace conventional antiscalants and/or cleaning solutions. Antiscalants are typically costly and pose a question of disposal. Acidic and caustic cleaning solutions are often prepared on site and require storage of toxic chemicals.

Carbon Sequestration For an in-line CO_2 application with concentrate disposal through underground well injection, this process could have the added benefit of carbon sequestration.

References
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2. Ngene, Ikenna S., et al. "CO2 nucleation in membrane spacer channels remove biofilms and fouling deposits." *Industrial & Engineering Chemistry Research* 49.20 (2010): 10034-10039.
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Acknowledgements Clemson University Dept. of Environmental Engineering and Science
Contact epartla@clemson.edu