



# Membrane Desalination of Agricultural Drainage Water

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*This project focuses on evaluating the integration of accelerated precipitation softening (APS) for scale mitigation with membrane RO desalting to enable high RO recovery. The technical and economic feasibility of the integrated APS/RO process and the practical recovery limits are being evaluated via laboratory evaluation using both brackish water field samples and model solutions along with computational model simulations.*

The salinity of brackish groundwater in the San Joaquin (SJ) Valley ranges from about 2000 to as high as nearly 29,000 mg/L total dissolved solids (TDS); in recent years, membrane desalination has been proposed as the practical technology to reduce this. Membrane desalination for SJ Valley brackish water would have to be carried out at relatively high water recovery in order to reduce the volume of generated reverse osmosis (RO) concentrate. However, at high water recoveries the concentration of mineral salt ions, on the feed-side of the membrane, may increase to levels that exceed the solubility limits of sparingly water soluble mineral salts (e.g., calcium sulfate, calcium carbonate and barium sulfate). As a result, these mineral salts may crystallize on the membrane surface and also precipitate in the bulk feed solution and deposit onto the membrane surface. This results in mineral scale build-up on the membrane surface that leads to permeate flux decline, shortening of membrane life, and consequently, reduction in process efficiency, increased operational cost and limitation on the maximum achievable product water recovery.

High recovery can be achieved if mineral salt scaling is alleviated. Accordingly, the present project focuses on evaluating the integration of accelerated precipitation softening (APS) for scale mitigation with membrane RO desalting. APS treatment

serves to de-supersaturate the RO primary feed or concentrate stream with respect to mineral salt scalants of concern. The demineralized stream can then be further desalted in a secondary RO stage to reach the target product water recovery. In the first phase of the project, a systematic theoretical thermodynamic solubility analysis was carried out to evaluate the limits on product water recovery due to mineral salt precipitation. This was done for five source water locations in the SJ Valley. The analysis revealed that, even with the use of anti-scalants and acidic pH adjustment, primary RO recovery in the five different locations would be in the range of 54%-76%. Recovery in excess of 90% is feasible, via secondary RO desalting of the primary RO concentrate, provided that the appropriate amount of dissolved calcium is removed by APS in order to de-supersaturate the RO concentrate. A design methodology was developed to determine the feasible primary RO recovery limit, the required percent of calcium removal by APS and the operating pH for the secondary RO stage. Such an approach will enable streamlining future RO pilot studies and aid in process scale-up.

Preliminary successful experiments were carried out to demonstrate the technical feasibility of the integrated RO-APS-RO desalting process. Diagnostic methods were developed to assess APS kinetics and the associated efficiency of reducing mineral

scaling propensity. Moreover, based on analysis of field water samples, the limits on primary RO recovery, as well as the pre-treatment needs for successful RO desalination have been identified. Continuing studies will provide additional valuable data necessary to estimate the cost of achieving up to 95% desalination recovery. Based on initial cost analysis, it is estimated that water desalination cost for the integrated RO-APS-RO process is in the range of typical brackish water desalination. However, it is noted that the reduction in concentrate volume could reduce the overall water production cost and make the process more environmentally acceptable relative to lower recovery brackish RO desalting processes.

### **Publications**

Rahardianto, A., J. Gao, C. J. Gabelich, M. D. Williams and Y. Cohen, "Accelerated Precipitation Softening for High Recovery Desalination of Low Salinity Brackish Water," *J. Membrane Science*, accepted.

Rahardianto, A., W-Y Shih, Lee R-W. and Y. Cohen, "Diagnostic characterization of gypsum scale formation and control in RO membrane desalination of brackish water", *J. Membrane Science*, 222, 1-14 (2006).

Shih, W-Y, A. Rahardianto, R-W. Lee and Y. Cohen "Morphometric Characterization of Calcium Sulfate Dihydrate (Gypsum) Scale on Reverse Osmosis Membranes," *J. Membrane Science*, 252, 253-263 (2005).

### **Professional Presentations**

Cohen, Y. "High Recovery RO Desalination of Brackish Water," Invited Presentation, 4th Chemical Engineering Conference for Collaborative Research in Mediterranean Countries, Le Meridien Hotel, Dead Sea, Israel, Jan. 9-11, 2006.

Cohen, Y., "Membrane Surface Nano-Structuring: Selectivity Enhancement, Fouling Reduction and Mineral Scale Formation," Invited Presentation, U.S. - Israeli Workshop on Nanotechnology for Water Purification, Arlington, VA, Mar. 13-15, 2006.

Cohen, Y., "Membrane Desalination of Agricultural Drainage Water - Opportunities and Limitations," Invited Presentation, Salinity Drainage Conference, Water Resources Center, Sacramento, CA, Mar. 29, 2006.

Cohen, Y., "Desalination Process Limitations and Enhancements," Invited Plenary Presentation, California/Nevada Section American Water Works Association (CA/NV AWWA) 2006 Spring Conference, Burlingame, CA Apr. 24-28, 2006.

Rahardianto, A., B.C. McCool, S. Rezvani and Y. Cohen, "High Recovery Desalination of Agricultural Drainage Water: Integration of Accelerated Seeded Precipitation with RO Membrane Desalination," CA/NV AWWA 2006 Spring Conference, Burlingame, CA Apr. 24-28, 2006.

Cohen, Y., "Desalination Process Development and Diagnostic," First Western Workshop on Water Technology Research," UCLA, Los Angeles, CA, Sep. 29, 2006.

### **Collaborative Efforts**

The California Department of Water Resources, Salinity Drainage Program has provided water samples from various locations in the SJ Valley. Water quality analysis was also provided for all samples. All of the above was provided as in-kind support.

The Metropolitan Water District of Southern California has provided antiscalant samples that were utilized in this study. A membrane concentrator, provided by MWD as in-kind contribution, was utilized in this study to evaluate high recovery RO desalination.

OLI Systems (Morris Plains, NJ) provided, at a significant discount, the LabAnalyzer 2.0 thermodynamic simulator that was utilized in this study for solubility analysis.

Hydranautics and Koch Membrane Systems have provided membranes as in-kind contribution for use in the present study.

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