Membrane Desalination of Agricultural Drainage Water

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The project focuses on evaluating the integration of accelerated chemical demineralization (ACD) for scale mitigation with membrane reverse osmosis (RO) desalting to enable high RO recovery. The technical and economic feasibility of the integrated ACD/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 Valley (SJV) ranges from about 2000 to nearly 29,000 mg/L total dissolved solids (TDS). In recent years, membrane desalination has been proposed as a practical technology to reduce the salinity of this brackish groundwater. Membrane desalination for SJV brackish water would have to be carried out at relatively high water recovery in order to limit the volume of reverse osmosis (RO) concentrate. However, at high water recoveries the concentration of mineral salt ions in the RO feed channel may increase to levels above the solubility limits of various sparingly water soluble mineral salts (e.g., calcium sulfate, calcium carbonate and barium sulfate). These salts crystallize directly on the membrane surface and may also precipitate in the bulk and subsequently deposit onto the membrane surface. Resulting mineral scale build-up on the membrane leads to permeate flux decline, shortened membrane life, and increased operational cost. High recovery RO desalting is feasible if mineral salt scaling, which limits recovery, can be alleviated.

This project focuses on evaluating an approach to high recovery desalting of brackish water that makes use of an interstage accelerated chemical demineralization (ACD) of the RO concentrate stream, in order to enable secondary RO desalting to further increase the overall product water recovery. In the first phase of the project, a systematic theoretical thermodynamic solubility analysis was carried out for selected source water locations in the SJV to evaluate the limits on product water recovery imposed by mineral salt scaling. The analysis revealed that, even with the use of antiscalants and acidic pH adjustment, primary RO recovery would range from about 58%-80%. Laboratory membrane scaling studies were then carried out for selected field brackish water samples from representative locations in the SJV to evaluate the scaling propensity of these source waters. These studies have shown that, for primary RO desalting of SJV brackish water (typically high in gypsum saturation), the carbonate ion suppresses gypsum crystallization while the sulfate ion suppresses calcium carbonate scaling. Therefore, RO operation can be carried out at a higher pH than would be predicted by thermodynamic solubility analysis. The addition of antiscalants can assist in enabling reasonable recovery in the primary RO step. The addition of coagulants to aid in feed pretreatment must be carefully evaluated as the present study revealed that filtration aids could severely reduce antiscalant effectiveness. Direct real-time RO membrane surface imaging was utilized to evaluate and compare antiscalant effectiveness. Such an approach can be used to rank antiscalant effectiveness, optimize dosage, compare candidate membranes based on scaling propensity, and optimize operating conditions.

Recovery up to about 95% was shown feasible, via secondary RO desalting of the chemically demineralized primary RO concentrate, based on lab experiments and a limited pilot plant study. Accelerated chemical precipitation, at high pH with calcium carbonate seeding, was found to be an

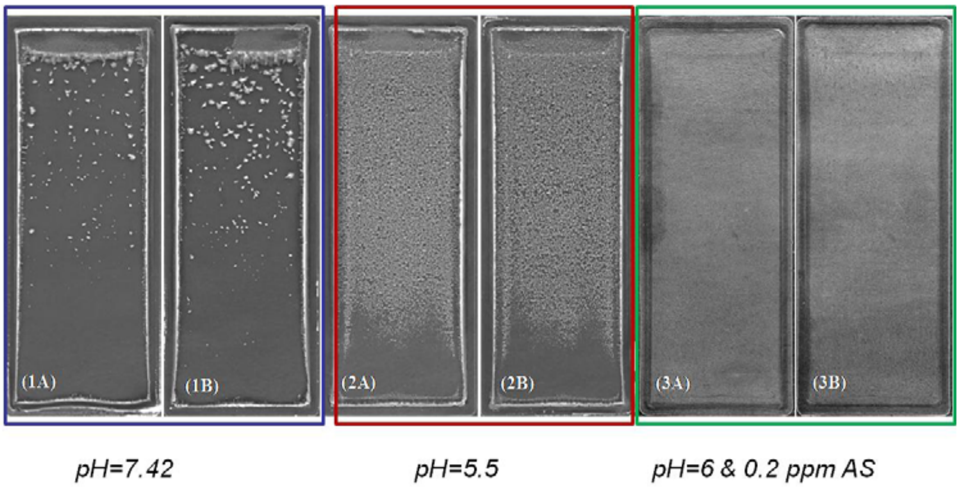

Figure 1. Images of gypsum scale formed on RO membrane from a scaling test with a dual membrane cell for a water source location in the SJV. Scaling is lower at pH 7.42 (the native pH of the water source) relative to pH of 5.5, due to the suppression of gypsum scale by the carbonate ion and suppression of carbonate scale by the sulfate ion. (Gypsum saturation index= 2.5)

effective demineralization method for primary RO concentrate rich in carbonate. However, chemical demineralization at high pH with gypsum seeding was more appropriate for desupersaturation of primary RO concentrate high in gypsum saturation, but with a low calcium carbonate precipitation potential. For this latter type of water source, recycling of the concentrate from the secondary recovery RO stage may be necessary in order to reach the target recovery level of >90%.

To evaluate the various process configuration options and optimal operating conditions for high recovery desalting, a process design methodology was developed for the integrated primary RO-ACD-secondary RO process. Laboratory studies confirmed that the precipitation kinetics was reasonably fast for practical implementation of the RO-ACD-RO desalting process. Current efforts are focused on evaluating the impact of antiscalant type and dose on the crystallization kinetics, with respect to the pH and size distribution of crystal seeds in the interstage crystallizer.

Selected Publications

Rahardianto, A., J. Gao, C. J. Gabelich, M. D. Williams and Y. Cohen. "High recovery membrane desalting of low-salinity brackish water: Integration of accelerated precipitation softening with membrane RO," *J. Membrane Science*, 2007 289 123–137.

Gabelich, C. J., M. D. Williams, A. Rahardianto, J. C. Franklin and Y. Cohen. "High-recovery reverse osmosis desalination using intermediate chemical demineralization," *J. Membrane Science*, 2007 301 131-141.

Selected Professional Presentation

Cohen, Y., "High recovery membrane RO desalination of brackish water: Opportunities and limitations", 233rd ACS National Spring Meeting. Mar. 27, 2007, Chicago, IL.

Collaborative Efforts

The California Department of Water Resources, Salinity Drainage Program provided in-kind contributions of water samples from various locations in the SJV and water quality analysis of those samples.

The Metropolitan Water District of Southern California provided antiscalant samples used in the study. A membrane concentrator used to evaluate high recovery RO desalination was provided as an in-kind contribution.

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 contributions for use in this study.

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