Membrane Desalination of Agricultural Drainage Water: Water Recovery Enhancement and Brine Minimization

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Executive Summary:

It is estimated that California faces a loss of significant areas of fertile agricultural land, due to gradual salinity buildup in the soil that will necessitates the continuing "retirement" of large areas of agricultural land, unless appropriate strategies for desalination of agricultural drainage water are implemented. In recent years, there has been a resurgence of interest in membrane desalination technology, in part, due to the availability of RO/NF membranes that can operate at remarkably low pressures with excellent product water flux and reasonably high levels of salt rejection. In the San Joaquin Valley in California, which is the region of interest in the present study, TDS levels are often in the range of 3,000-15,000 mg/L with calcium and sulfate levels close to saturation with respect to gypsum (CaSO4. 2H2O). At water recovery levels that are required to meet the TDS level for agricultural water reuse (~750 mg/L) and make the desalination process economical, the concentration of mineral salt ions on the feed-side and near the membrane surface increase to levels that exceed the solubility limits of calcium sulfate, calcium carbonate, barium sulfate and possibly other salts. The ensuing crystallization of these sparingly soluble mineral salts, onto on the membrane surface and surface deposition of bulk crystals results in scale build-up, leads to permeate flux decline, shortening of membrane life, and as a consequence reduction in process efficiency and increase in operational cost.

Although advances have been made in reducing technical problems associated with membranes fouling (due to particulate and colloidal matter), surface scaling of RO membranes by mineral salts remains a major road block to wide-spread (and large-scale) implementation of this technology for desalting of agricultural drainage (AD) water. Control of calcium carbonate scaling by pH adjustment has been successful; however, this approach is not effective for control of scale formation due to calcium sulfate and barium sulfate salts. These salts are responsible for the major scaling problem in membrane desalting of AD water. Limited field studies in the San Joaquin Valley and laboratory investigations at UCLA have shown that membrane desalination of AD water would have to be limited to about 50-75% product water recovery (even with the use of antiscalants) in order to avoid membrane surface scaling. In this water recovery range, the volume of concentrate (brine) stream is significant and thus represents a loss of valuable water resource and a major disposal challenge. Therefore, it is imperative to

develop technologically and economically feasible means of increasing water product recovery in membrane desalination of AD water.

It is proposed to explore two approaches of increasing water product recovery to a level of at least 98%. In the first approach, the water feed will be treated by an accelerated precipitation (ACP) process to primarily reduce calcium ion concentration, followed by RO desalination. The accelerated crystallization will consist of seeded-crystallization with calcium carbonate coupled with pH adjustment to about pH~9.5 (with sodium hydroxide). With typical AD water containing calcium ions in the range of 1000-15,000 mg/l, accelerated crystallization should enable reduction of calcium and barium ion concentrations by up to about 80-90%, thereby reducing the saturation level of their sparingly soluble sulfate salts below the critical concentration at which membrane surface scaling is induced in the RO process. It is noted that mineral surface scaling due to calcium carbonate can be easily avoided by lowering the feed pH to below 6 prior to RO desalting. Therefore, the treated feed can then be further desalted by RO treatment to achieve high water recovery. In the second alternative process configuration, AD feed water will be first desalted in a primary RO process to a level of about 50%-75% recovery, followed by ACP treatment of the brine stream, and then a secondary RO desalting to reach the targeted water product recovery of up to 98%.

The proposed research will focus on laboratory evaluation of the coupled ACP/RO processes with models solutions at the composition range expected for AD water from the San Joaquin Valley. Seeded crystallization will be carried out in a batch crystallizer and membrane desalination will be carried out in a laboratory spiral-wound membrane desalination unit. Process effectiveness, with respect to alleviating surface scaling, will be evaluated by both membrane autopsies and through diagnostic measurements in a plate-and-frame membrane desalination system. Once optimal process conditions are established, the coupled ACP/RO process will be demonstrated with actual field water. The study will provide information necessary for the design of future field pilot demonstrations of the ACP/RO process and for the evaluation of the technical and economic evaluation for field implementation of this process. The results of this study will be useful for various California counties and local water districts faced with the problem of increased AD water salinity. The study will also be of direct interest to the California Department of Water Resources and the United States Bureau of Reclamation.