

# **Desalination of Agricultural Drainage Water and Concentrate Minimization: Integration of RO with Accelerated Chemical Demineralization and RO Feed Flow Reversal**

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## **Executive Summary**

The San Joaquin Valley (SJV) is destined to lose significant areas of fertile agricultural land, due to gradual salinity buildup in the soil that will necessitate the continuing “retirement” of large areas of agricultural land, unless appropriate strategies for desalination of agricultural drainage water are implemented. At the same time, the need for potable water sources is rapidly increasing due to continuing population growth. In certain areas of the SJV agricultural drainage water is being disposed of by evaporation, thereby representing a net loss of water that could be potentially be reclaimed and reused. Reverse osmosis (RO) and nanofiltration (NF) membrane desalination can provide a viable technological approach of producing high quality water (for either agricultural reuse and/or potable water consumption). Membrane desalting can be achieved at remarkably low pressures with excellent product water flux and reasonably high levels of salt rejection. The salinity of SJV drainage water is the range of ~3,000-30,000 mg/L with calcium and sulfate levels often close to saturation with respect to gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ). At water recovery levels that are required to meet the recommended TDS level for potable water consumption (~ 500 mg/L) or agricultural water reuse (~750 mg/L), 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 surface crystallization of these mineral salts and the deposition of their bulk crystals onto the membrane surface result in mineral surface scale. This leads to water permeate flux decline and potential damage to the membrane and thus shortening of its useful lifetime. As a consequence, process efficiency is reduced and water production cost increases. It is also noted that, the composition of drainage water varies with time (with respect to salinity and the composition of sparingly soluble mineral salts) and correspondingly the mineral scaling propensity of such water is also time-dependent. Current design and operation of RO systems are not effective for handling temporal variability of feed water quality. Therefore, in order to enable effective implementation of RO/NF technology in the SJV, there is a need to develop and demonstrate a cost-effective and robust desalination control that is self-adaptive and capable of mitigating mineral scaling.

Although advances have been made in reducing membranes fouling (due to particulate, bacterial and colloidal matter), surface scaling of RO membranes by mineral salts remains a major obstacle 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 due to calcium sulfate and barium sulfate salts, which are the major scalants in membrane desalting of AD water. 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 50-70% product water recovery, even with the use of antiscalants, in order to avoid membrane surface scaling. Antiscalants can add up to about 15% of the total cost of water production. Their use can also represent an environmental challenge with respect to disposal of the residual concentrate. Antiscalant can also stabilize mineral salts in the concentrate, thereby making it more difficult to implement salt removal strategies based on chemical demineralization. Therefore, it is imperative to develop technologically and economically feasible means of achieving a reasonable water product recovery by avoiding scale formation while eliminating or minimizing the use of antiscalants.

In order to enable product water recovery at sufficiently high levels (up to 90-95% in some cases), it is proposed to explore the integration of RO/NF membrane operation in a feed flow reversal mode with accelerated chemical demineralization (ACD). RO or NF membrane desalting will be first utilized to accomplish a first stage desalting up to the recovery limit (~50%-75%) that would be possible with a feed-flow reversal operational (FFRRO) mode. In this operational mode the direction of the feed flow is periodically switched (between the membrane module ends), so as to continuously remove scale that forms at the exit region of the module (this being periodically switched to become the inlet region). In order to enable the above operational mode, a novel scale monitor (developed at UCLA) will be implemented to provide detection of the onset of surface mineral scaling. The above operational mode will enable a significant reduction of the required dosage of antiscalants or may even allow completely eliminate the need for antiscalant dosing. In order to increase product water recovery, an interstage accelerated chemical demineralization (ACD) will be implemented to reduce the concentration of mineral scale precursors from the primary RO concentrate (PRO), followed by a secondary membrane desalting stage. Recent work at UCLA has shown that the high sulfate ion concentration, and relatively low carbonate ion concentration, in SJV drainage water would result in reduction gypsum precipitation due carbonate adsorption onto gypsum crystal surfaces, while sulfate appears to reduce calcium carbonate precipitation. Therefore, chemical demineralization can be best accomplished by increasing alkalinity (to pH~9.5-10.5) of the PRO concentrate using calcium hydroxide, along with gypsum crystal seeding to reduce gypsum, calcite and barite scaling. The ACD treated and filtered PRO concentrate will then be desalted in a secondary RO (SRO) stage (to a level of ~50-75%), again using the feed flow reversal operational (FFRRO) mode. The above water desalting approach should enable operation that free of the limitations imposed by mineral salt scaling, while enabling up to possibly ~90-95% recovery using ACD with a secondary RO desalting stage.

The proposed research will focus on laboratory development and demonstration of the integrated FFRRO/ACD desalination processes with models solutions and field water from the San Joaquin Valley. ACD will be first optimized for the SJV water source, which will be used in the pilot field study, in a batch crystallizer and membrane desalination will be carried out in a laboratory membrane desalination unit. Once optimal process conditions are established, the FFRRO/ACD process will be demonstrated in a field study (in collaboration with the Tulare Lake Drainage District and the California DWR) using a fully automated pilot FFRRO system currently under development at UCLA. The study will provide information necessary for evaluation of the technical and economic feasibility of large-scale implementation of the FFRRO/ACD technology for producing potable water from AD water and for AD water reuse. Results of this study will also be useful to various California counties and local water districts faced with the problem of increased AD water salinity.