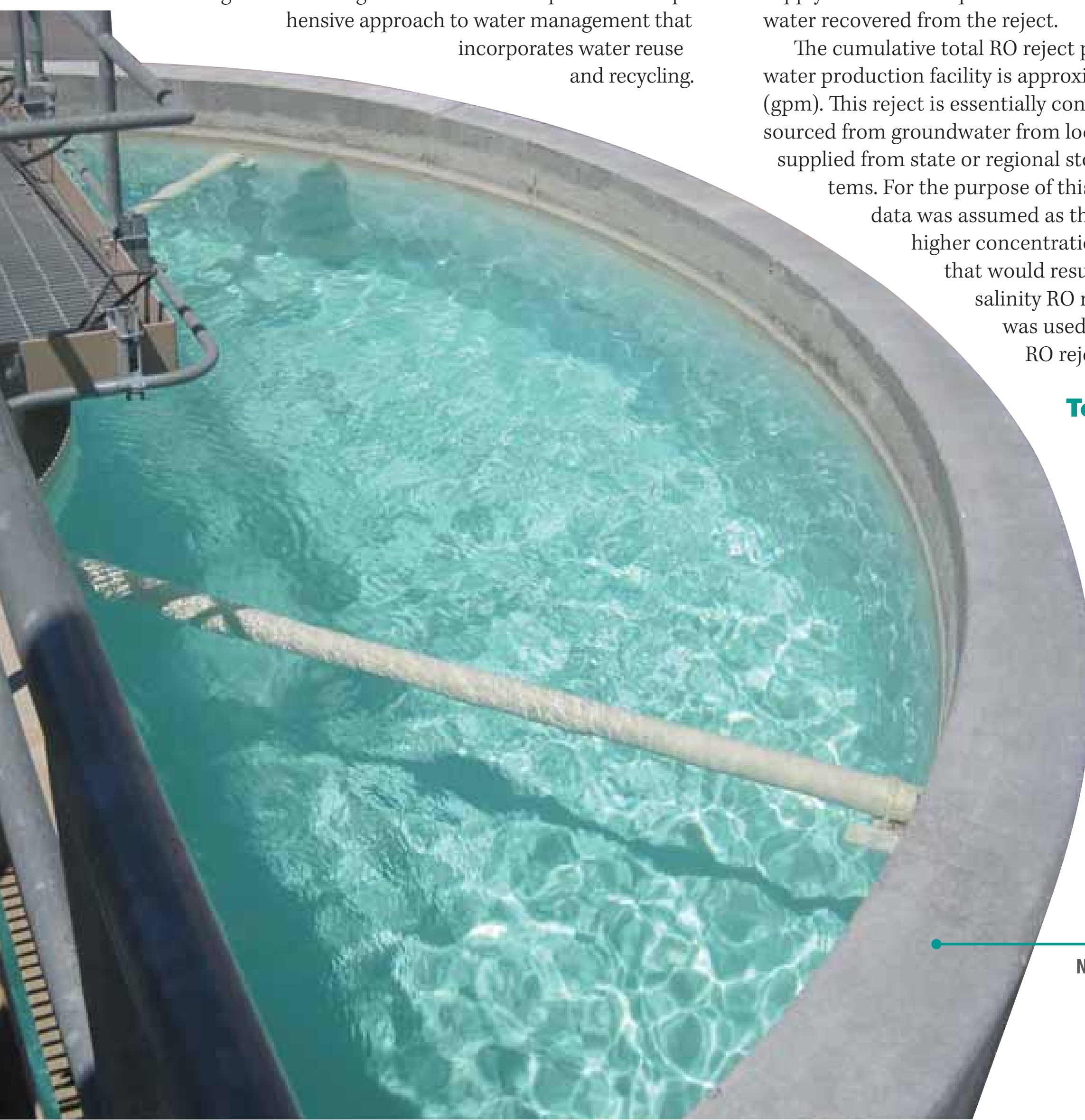
Solutions for the Water-Scarce

Utilizing RO concentrate treatment & reuse yields sustainable water management schemes

By James Lozier, Michael Hwang & Ralph Williams

As water-intensive industries such as specialty manufacturing, power generation and mining continue to locate in relatively arid and water-constrained geographies, they are faced with water supply and wastewater disposal issues that are becoming increasingly complex and expensive.

The disposal of the high-salt waste produced from RO, called reject (or concentrate), is a challenge due to the lack of naturally occurring surface waters in which to discharge, or limitations on disposal to sewers because treated effluent is used for landscape irrigation or other non-potable applications. These constraints—lack and quality of water supply and difficulties with high-salt discharges—are forcing industries to develop a more comprehensive approach to water management that incorporates water reuse and recycling.



Nevada lime softening system

These strategies include innovative approaches to RO reject management and, in an effort to reduce overall water demands, reusing treated wastewater and limiting the volume of RO concentrate requiring disposal.

This article describes a water management study conducted in the arid southwestern U.S. to evaluate treatment options for a high-salinity RO reject that is produced as a waste stream from high-purity water production. Increasing RO reject flows, coupled with a fixed volume within existing solar evaporation ponds for concentrate disposal, required the development of new approaches to reducing overall reject flows. Furthermore, water supply limitations required the treatment and reuse of the clean water recovered from the reject.

The cumulative total RO reject produced from the high-purity water production facility is approximately 2,000 gal per min (gpm). This reject is essentially concentrated city (potable) water, sourced from groundwater from local wells and surface water supplied from state or regional storage and conveyance systems. For the purpose of this study, historical groundwater data was assumed as the water supply because it has higher concentrations of TDS and inorganics that would result in the production of higher-salinity RO reject. IMSDesign software was used to estimate the quality of the RO reject.

Technology Overview

A variety of technologies was considered to treat the RO reject and minimize brine flows to meet the capacity of existing solar evaporation ponds—and to produce a high-quality permeate suitable for reuse that would maximize overall water recovery. Membrane-based desalination was assumed to be the most effective technology. High levels of scaling salts in the untreated RO reject, however, meant

Brine concentrators and evaporators

that pretreatment would be required to soften the water to maximize recovery of the desalination process. Further, in order to overcome osmotic pressure (RO) or voltage (EDR) limitations, additional brine concentration technologies downstream of these processes would be needed to achieve a brine flow of a suitable volume for disposal in the allotted acreage of evaporation ponds. These technologies included the following:

Precipitative softening. This technology was selected as the first step to remove calcium, magnesium, alkalinity and silica from the reject. The softening reactions also coprecipitate barium, strontium and fluoride, which can form precipitates and limit the recovery of the downstream desalination process.

Results of the modeling, bench testing, site-specific requirements and cost analysis found that lime and soda ash chemistry executed using a high-rate conventional solids contact reactor/clarifier was the most cost-effective and reliable softening and clarification process to achieve the desired water quality.

Softened water filtration. The clarified, softened reject must then be filtered to remove residual suspended solids prior to desalination. This can be achieved using either granular media filtration (GMF) or membrane filtration (microfiltration/ultrafiltration [MF/UF]). The former is less expensive (capital and operations), does not produce a chemical waste stream, has a lower footprint, can be housed outdoors and generates less overall wastewater flow. The primary disadvantage of GMF is that the filtered water produced will be of lower quality compared with that produced by membrane filtration. This is only important if the downstream desalination process being utilized is RO.

In this application, the cost and footprint advantages for GMF outweighed the filtrate quality advantages inherent to MF/UF.

Desalination and volume reduction. After reducing its scale-forming tendencies, the RO reject can be processed by one of two energy-efficient desalination processes: RO or EDR. Two different RO configurations were evaluated based on a conventional design and the high-efficiency reverse osmosis (HERO) process. EDR, an electroseparation process utilizing ion exchange membranes, was evaluated because of its potential to achieve a higher recovery than RO. The projected EDR product, however, did not meet the reuse requirements, particularly for TOC and silica, and would require polishing using additional processes (such as RO), so EDR was not considered any further.

The primary value of HERO and conventional RO lies in their ability to achieve maximum recovery without being limited by mineral precipitation, particularly that of silica.

Further volume reduction using mechanical evaporation. To achieve further volume reduction, the concentrate from the conventional RO process can be processed by a mechanical evaporator. Traditionally, in the power and industrial sectors, mechanical evaporators (also known as brine concentrators) and crystallizers, which utilize thermal-based distillation to separate water from the desalination process brine, often are used to reach near-zero or zero liquid discharge.

Because of their high capital and operating (energy) costs, a non-conventional RO technology using a "disc tube" configuration that can operate at feed pressures up to 1,600 psig also was considered. A technical and cost evaluation of these technologies indicated that the thermal evaporative processes would be the best choice for RO concentrate volume reduction, primarily due to the significantly higher recovery that can be achieved.

Evaporation ponds. An evaluation of the existing solar evaporation ponds was conducted to determine their ability to evaporate the brine from the mechanical evaporator. A model was used to calculate real-time values for water level, salt accumulation, and ultimately, the duration of pond operation until the time that either overflow occurs or the ponds must be taken out of service to remove the accumulated salt. Modeling found salinity of the incoming brine to be the most critical factor affecting pond evaporation rate and that at any flow, the higher the salinity, the shorter the period before water level reached overflow. Based on the RO reject flow, a treatment system would be required to reduce the reject volume enough to utilize the calculated capacity of the existing evaporation ponds.

Alternative (distillation-only) approach. Based on the analyses, a "base case" solution for volume reduction of the RO reject was developed that included precipitative softening, conventional RO, mechanical evaporation and a mechanically driven brine crystallizer. While the treatment train would be capable of reducing the RO reject flow from 2,000 to 43 gpm

while recovering 1957 gpm as high-quality water for reuse, the operating cost of this train was significantly higher than originally anticipated; this was primarily because of costs associated with precipitative softening as well as the need for further brine volume reduction using a crystallizer in order to attain a brine flow that could be adequately evaporated in the ponds.

These costs were significant enough to investigate an all-distillation approach that included multiple mechanical evaporators and a crystallizer. While the alternative has higher capital cost and annual energy requirements, a comparison of the lifecycle costs showed that the alternative approach would result in cost savings of $30 million over 20 years (at 10% discount rate). In addition, this alternative would produce higher quality product water, be much simpler to operate due to the reduced number of unit processes, and eliminate truck traffic associated with delivery of lime and soda ash as well as removal of lime-based sludge.

Assessing Findings

The findings from this case study illustrate that disposal of brackish waste streams, exemplified here by an RO reject produced from purification of a higher-salinity municipal water supply, is both challenging and expensive. While the use of membrane-based desalination may appear to be less expensive based on its considerably lower energy use, the need for chemically intensive pretreatment can result in a higher total water cost than thermal-based desalination methods, depending on the degree of volume reduction necessary.

The results presented herein underpin the need for an effective industrial water management approach that moves away from the "use-it-once-and-discharge" approach to one that balances high-purity water production and sustainable management of saline waste streams with the objective of maximizing recovery and reuse—ultimately minimizing environmental impact. iWWD

James C. Lozier is global technology leader for desalination, Michael Hwang is associate engineer and Ralph Williams is principal technologist with CH2M Hill. Lozier can be reached at jlozier@ch2m.com. Hwang can be reached at michael.hwang@ch2m.com. Williams can be reached at ralph.williams@ch2m.com.