RO Cleaning Frequency: A Balance of Costs

Economic analysis: A California groundwater replenishment system application

The OCWD GWR features an RO system comprised of 15 trains.

By Eric Owens & Mehul Patel

Over the last two decades, reverse osmosis (RO) has become the process of choice for removing dissolved salts and other contaminants from a variety of water sources, including seawater, groundwater and wastewater effluents. RO is a pressure-driven process, where the applied pressure required to drive water through the membrane is a function of the total dissolved solids (TDS) in the feed source. As foulants build up on the membrane surface, the foulant acts as an impediment to flow and the pressure required to drive water through the system increases. Left alone, the fouling can build up until the required pressure exceeds the feed pump capabilities, and a loss of permeate production eventually will occur. Membrane cleaning is used to remove the foulant from the membrane surface and return the system to baseline conditions.

RO technology has been adopted by both industrial and municipal users. Industrial RO systems are often smaller (less than 1-million-gal-per-day [mgd] permeate capacity) and sometimes designed without the ability to clean the membrane elements in place within the pressure vessels. In these cases, operators either send membrane elements off site for cleaning, or elements are simply discarded when they have been completely fouled.

Municipal systems are often large scale, and they typically range between 1 mgd and 100 mgd in permeate production. Individual RO train capacities typically range from 0.5 mgd to 5 mgd. The size of municipal facilities usually requires an operating approach whereby a membrane that is eventually fouled during the treatment process is cleaned in situ using a chemical solution selected based on the type and nature of the foulant on the membrane surface. The cleaning solution is introduced into the membrane system through an ancillary cleaning system. For large municipal systems, membrane cleaning in this manner is more economical and practical than offsite cleaning or replacing the membrane. Through membrane cleaning, the pressure required to operate the RO system is reduced, and hence the energy consumption is minimized.

Calculate to Optimize

There are industry rules of thumb as well as specific RO manufacturer guidelines for when and how to clean RO membranes. These typically revolve around the parameters of water permeability and normalized differential pressure. Calculated indicators of water permeability (e.g., specific flux, normalized feed pressure, normalized permeate flow and normalized flux) can be used as indicators of the amount of fouling on the membrane surface. The normalized differential pressure offers an indication of the amount of material deposited within the feed/brine spacer of the RO elements, restricting flow through the system.

Guidance on membrane cleaning from the industry suggests cleaning the RO train when the water permeability has decreased by 10% to 25%, or when the normalized differential pressure has increased by 20% to 50%. This guidance, however, does not necessarily offer the most economical point of operation for the RO system.

RO cleaning can be considered nothing more than a response against increasing system pressures and energy costs. But rather than follow anecdotal cleaning triggers, operators should examine the balance between the cost of energy associated with fouling and the cost of performing the cleaning for their particular system. All RO systems are somewhat different, and there are many variables that contribute to this examination. In order to identify a balance between fouling and cleaning, the following variables must be considered for a particular system:

- Cost of energy paid by the municipal agency;
- Specific fouling rate of the RO system;
- The nature of the foulant and cleaning effectiveness;
- Total cost of chemical solution;
- Labor associated with performing a cleaning; and
- Lost permeate production due to downtime during cleaning.

One such examination was performed for the RO trains within the Orange County Water District's (OCWD) groundwater replenishment system (GWR) in California. The following is a discussion of the economic analysis performed for this RO system in order to identify the balance between fouling costs and cleaning costs. Ultimately, this economic analysis was successful in identifying the optimum cleaning interval given the specific GWR variables.

Case Study: OCWD GWR System

The RO system for the OCWD's GWR consists of 15 RO trains, each with a 5-mgd capacity, for a total plant production of 70 mgd of RO permeate capacity (N+1 design). The RO trains operate at 85% recovery and a maximum permeate flux of 12 gal per square foot per day. Each train houses 1,050 8-by-40-ft Hydranautics' ESPA2 RO elements in a 78:48:24 array (seven elements per vessel).

The membranes within the 15 GWR RO trains have a range of permeability due to intrinsic differences in membrane construction, cleaning effectiveness or exposure to different events and conditions during startup and operation. The inherent permeability of the membrane is the first contributor to the energy costs for an RO system. The second component contributing to the energy costs is the unique fouling rate identified for each train following a cleaning. While this fouling rate is generally anticipated to be similar between trains (due to similar operating conditions), this is not the case for all 15 trains at OCWD. Several trains have demonstrated sharper fouling rates than others. This may be due to previous, less-effective cleanings, varying hydraulics between trains or some indeterminate issue. Whatever the influences, these two components have contributed to distinct performances and energy costs associated with individual RO trains. For this reason, each individual train was analyzed to determine the most cost-effective cleaning alternative for operating that specific RO train.

Because RO trains may operate within a range of flow conditions, temperature and feed salinities, it is not practical to use the actual energy consumption of a given train for this analysis. Instead, the data was normalized in order to represent operation at 5 mgd RO permeate, 1,800 µS/cm feed conductivity and 77°F feedwater temperature.

The fouling rate of each train was determined from the normalized feed pressure calculated after membrane cleaning occurred. The typical normalized feed pressure trend for membranes operating at the GWR starts out with a steep increase that is followed by a somewhat linear performance. The linear portion of the trend is generally developed within 20 days of the cleaning. For this reason, the performance 20 days after a cleaning was used to model the long-term fouling rate of the individual trains. Based on historical performance at GWR, this linear fouling rate was considered representative of the anticipated fouling rate and used to extrapolate the long-term train performance.

A linear model may not offer the best fit for all fouling trends. This expectation should be confirmed as fouling progresses and an appropriate model selected based on actual system performance. This fouling trend model was used to investigate the costs associated with several cleaning interval scenarios.

This analysis also assumed that membrane cleanings were consistently effective, regardless of the frequency between cleanings. This goes against the typical operational expectation that as more foulant builds on the membrane surface, the more difficult it will be to remove through cleaning. But based on historical performance data for GWR, this was

All RO system operators should analyze energy and cleaning costs to find a balance between cost-effectiveness and performance.

considered an acceptable assumption for this RO system. Other RO facilities with different fouling characteristics and cleaning effectiveness may not be able to make this assumption if consistent and repeatable cleanings cannot be achieved.

The cost associated with membrane cleanings included the labor cost, the chemical costs of the district's cleaning procedure and the cost of lost production due to offline time. While the GWR system design accounts for one of the 15 trains being offline (N+1), it was assumed the fifteenth train could be offline for any number of other reasons; lost production due to cleaning was factored into this analysis. For this investigation, the total cleaning cost amounted to $15,929 multiplied by the number of cleanings per year.

Even though the energy costs decrease with an increased frequency of cleanings, the reduced energy costs are offset by the additional cost of the cleanings. This investigation was taken further to determine the minimum operation and maintenance (O&M) costs for CIP intervals ranging from 30 days to 365 days. The total cleaning and total energy costs were compared and combined for this range of CIP intervals in order to determine the optimum cleaning interval that offered the minimum total operating costs.

Summing the two costs together resulted in a "Total O&M Cost" curve with a shape similar to that of a parabola. In this presentation, the total O&M costs toward the lefthand side of the parabolic curve are heavily weighted toward chemical costs due to frequent cleanings. The total O&M costs to the righthand side of the parabolic curve are more heavily weighted toward energy costs as a result of accepting more fouling within the RO train. The minimum O&M costs can be determined by identifying the minimum point on the curve.

This analysis was applied to each RO train and its unique condition and fouling rate in order to determine the minimum total O&M costs related to cleaning and fouling. Depending on the unique performance of each train, the optimum cleaning interval could fall on either side of the six-month interval.

The results of the analysis of 15 individual trains were as follows: The most economical cleaning frequency for seven of the trains was determined as every five months. The most economical cleaning frequency for seven of the trains was calculated as every eight months. One RO train calculated an optimum cleaning frequency of every 10 months. The optimum CIP interval and minimum annual energy and CIP costs were determined from the parabolic curves for each train.

Adopting a Similar Approach

Industry standards for CIP triggers may not offer the most efficient point of operation for RO systems. An economic analysis investigating the balance between energy costs and cleaning costs should be applied to any RO system to ensure that the current cleaning regime offers the most cost-effective operation and performance. The analysis described herein was based on a combination of real-world data and observations but assumes the cleanings applied are consistently effective. It also assumes the modeled fouling rates are observed and repeatable following each cleaning.

This is generally the case at OCWD, but should the fouling rate or cleaning effectiveness deviate from the model, the evaluation would need to be redone. If this analysis indicates the benefit of a longer cleaning frequency, it would be wise for operators to confirm their assumptions through gradual implementation of longer cleaning frequencies. This would allow verification of the modeled fouling rate and confirm consistent cleanability is achieved.

A significant savings of approximately $250,000 per year was identified at OCWD through performing an economic analysis to identify the optimum cleaning interval for the district's system. Not all RO systems are guaranteed the same degree of savings determined for OCWD, but most would likely benefit from applying a similar approach to their cleaning philosophy. MT

Eric Owens, P.E., is project manager for Separation Processes Inc. Owens can be reached at eowens@spi-engineering.com. Mehul Patel, P.E., is principal process engineer for the Orange County Water District. Patel can be reached at mpatel@ocwd.com.

For more information, write in 1103 on this issue's Reader Service Card or visit www.wwdmag.com/lm.cfm/mt101003.


Delivering Complete MBR Solutions

TITAN™ MBR

- The Industry's Most Economical MBR System
- Backed by S&L Process Engineering Experience
- Non-Clog S&L Flat-Plate, Clean-in-Place Membranes
- Ideal for Municipalities, Industry & Private Development

Ask About Doubling Your Existing Plant Capacity with a TITAN MEM-BOX™ Retrofit System!

Large Flows | Packaged Systems | Retrofit Systems
800-898-9122 | smithandloveless.com

Smith & Loveless Inc. S&L

Write in 401


Ultrameter II™ 6Psi

NEW! bluDock™ Wireless Data Transfer (optional)

NEW! LSI and Hardness Calculator

www.myronl.com

CONDUCTIVITY, RESISTIVITY, TDS, pH, OPR, FREE CHLORINE & TEMP

Write in 402