AIChE JOURNAL Highlight

A Bright Future for RO Water Desalination

Water scarcity and groundwater contamination have sparked major efforts to preserve and diversify regional water portfolios through water desalination and water reuse. While various approaches exist, reverse osmosis (RO) membrane desalination has emerged as the dominant technology for seawater and brackish water desalination in small- to municipal-scale applications. RO-based desalination makes up 65% of worldwide desalination capacity, followed by multistage flash evaporation (21%). The remaining 14% of the capacity includes multiple-effect distillation, vapor compression, and electrodialysis reversal.

In the June *AIChE Journal* Perspective article, "A Perspective on Reverse Osmosis Water Desalination: Quest for Sustainability," Yoram Cohen and Raphael Semiat of the Univ. of California, Los Angeles, and Aditya Rahardianto of the Technion–Israel Institute of Technology, provide an overview of RO-based desalination, identify challenges associated with this technology, and discuss the various factors that contribute to the overall cost of RO desalination.

RO desalination relies on a semipermeable membrane that allows water permeation but rejects dissolved solids. The feed side of the membrane is pressurized to a level above the osmotic pressure to provide the desired permeate water flux. The RO process is driven by a pump for fluid conveyance and for generating the required feed pressure. An intake system is required to convey the feedwater from the source to the plant, and a concentrate-management system is required to handle the high-salinity concentrate (or brine). Two issues associated with this type of desalination are fouling and mineral scaling.

"The levels of suspended solids, organics, and microorganisms in the RO feed must be reduced to a sufficient level to avoid fouling of the RO membranes," the authors write. "RO operation can also be negatively impacted by mineral scaling, which can occur when the concentration of sparingly soluble mineral salts in the RO feed rises above their solubility limit as product water is extracted. The consequence is mineral salt precipitation and scale formation on the RO membrane. Membrane fouling and mineral scaling lead to membrane surface blockage and, as a result, degradation of membrane performance, which can shorten membrane longevity and increase operational costs."

Several approaches to address fouling and scaling exist. To prevent membrane fouling, foulants are typically removed from the feedwater prior to desalination via conventional flocculation/coagulation, disinfection, media filters, or membrane filtration processes. Mineral scaling is typically mitigated with one of several methods, including the addition of polymeric antiscalants to the feed to suppress the nucleation and/or growth of mineral crystals; feed pH adjustment if calcium carbonate is present; periodic membrane cleaning; and the removal of scale precursors via crystallization, nanofiltration, or ion exchange.

When considering RO desalination, it is important to evaluate costs. The total cost of a typical RO desalination plant generally consists of the cost of energy consumption, equipment, membrane replacements, residual concentrate management, labor, maintenance, and finance charges. The cost breakdown can vary significantly and depends on plant size and location, the quality and salinity of the water source, and local electrical energy costs. Energy costs typically account for a large portion of the overall cost.

"Because seawater RO is energy intensive, the costs of seawater RO are often considered high," the authors write. "However, this can be misleading, as often desalination costs are not compared to the costs of locally available (and feasible) alternatives," they continue. "The energy cost of desalting brackish water is lower than for seawater. However, unlike seawater RO plants, the management of the RO concentrate from inland brackish desalination can represent a major challenge given the often limited options for concentrate disposal."

Through thermodynamic arguments, Cohen and his colleagues demonstrate that the current state-of-the-art RO desalination technology consumes close to the minimum amount of energy. This is largely due to the availability of RO membranes with reasonably high permeability that enable operation approaching the cross-flow thermodynamic restriction limit. The ability to recover energy from the retentate stream via highly efficient energy-recovery devices also contributes to the minimization of energy consumption. Although membranes with higher permeability would allow RO desalination plants with a smaller footprint, higher-flux operations would be required to maintain permeate water productivity, which would increase the propensity for membrane fouling and mineral scaling, the authors caution.

"Although there are various proposed alternatives to RO desalination, to date, none have been shown in field studies to be superior to RO desalination for large-scale applications of potable water production. However, it is conceivable that future developments will drive the competition, which will ultimately lead to the expansion and broader acceptability of desalination technologies as an important step toward water sustainability," they conclude. CEP

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