

## The Global Challenge of Sustainable Seawater Desalination

Seawater desalination is here to stay, and not just in historically arid areas such as the Middle East, but in many places around the world where rivers used as a water source no longer reach their original destination or have insufficient flow once they do. Southern California is particularly being challenged by a lack of freshwater, so new seawater desalination plants are being planned or built in many locations such as Huntington Beach and Carlsbad. Changing precipitation and runoff patterns, increased upstream water use, and the thirst for clean and contaminant-free water have stimulated the increased use of membrane processes in water treatment in general, but limited water supplies in many parts of the world are increasingly reliant on seawater desalination. Investments in reverse osmosis (RO) desalination plants are spiraling upward, with an estimated US \$21 billion spent last year, and double that expected for 2020. The good news is that RO desalination plants can operate at efficiencies approaching practical thermodynamic limits based on osmotic pressures, thanks in large part to improved membranes and pressure recovery systems. However, the estimated 18000 or more desalination plants in the world are mostly powered using fossil fuels. The use of solar, offshore wind, and other forms of renewable energy could help to address this issue of energy sustainability; however, there are other challenges to ensuring the sustainability of desalination, and insufficient attention is being paid to deal with these challenges, especially in the United States.

RO membrane fouling remains the top challenge. While there are many research teams working on fouling in general, too much research in the past has been wasted on studying it, describing it, and publishing papers that observe but ultimately do not improve fouling rates. However, there is hope in slowing fouling based on new approaches, such as chemical modification of the membrane surface or reactive membranes that can reverse fouling due to disruption of unwanted chemical bonds. New, more radical and effective approaches are needed to minimize membrane fouling.

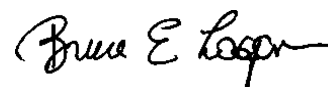
Spent RO modules are another problem. Spiral wound membranes are housed in containerized plastic modules, and when the membranes can no longer be cleaned, the module becomes a waste product. In some areas in the world, modules are simply landfilled, but in other land-limited areas, their disposal can be a problem. One solution to reduce module waste is to greatly improve the water flux, thus allowing the water treatment rates with fewer modules than current systems require. Work on artificial water channels using nanotubes or molecules that mimic water transport proteins in membranes called aquaporins is a fascinating route for improving water flux. However, without advances to greatly reduce fouling, higher water flux could just translate to greater fouling rates with little impact on module wasting rates. A higher water flux will also result in greater concentration polarization, which could increase energy consumption, compromise selectivity, and lead to additional chemical fouling on the membrane surface.

New approaches that desalinate water while avoiding water flow through membranes should be more actively investigated. Capacitive deionization (CDI) and electrodialysis (ED) are the two most well-known alternatives to RO desalination, but they

have yet to have a global impact. Both processes are considered to be useful for brackish water, but they are so far not well suited for high-salt removals needed for seawater desalination. In both processes, ions are moved through the membrane to form brines, as opposed to water being pushed through a membrane. The transport of ions rather than water could help to prevent the type of fouling seen in RO units, but relatively little has been done to examine fouling challenges for these systems.

All desalination systems are eventually reduced to the same final challenge of dealing with the brine. Returning the salt to the sea with ample dilution can offset certain impacts on the marine ecosystem, although inland systems do not have this option. For many cities, there are opportunities for additional power generation using these brines and additional seawater. Salinity gradient energy techniques such as pressure-retarded osmosis (PRO) or reverse electrodialysis (RED) could be used to regain some of the lost energy in RO by producing electricity using the brine and additional seawater, through combined RO–PRO or RO–RED systems. Used water (better known in the past as treated wastewater) is another opportunity for electricity generation using salinity gradient energy. Many large cities currently discharge used water, which has been treated to a very high level, into the ocean. In the United States on the east coast, cities such as New York, Philadelphia, and Washington, DC, could find energy production using salinity gradient techniques useful for turning used water plants into energy recovery or net-energy-producing plants.

Seawater desalination and salinity gradient energy technologies are critical to the continued success of our water infrastructure. We need to increase our national investment in these technologies to ensure the safe and sustainable water supplies into the future. Research on reducing membrane fouling can help in the near term, but in the long term, we must find new and more sustainable methods for water production by desalination and energy recovery using salinity gradient energy technologies.



Bruce E. Logan<sup>✉</sup>

### AUTHOR INFORMATION

ORCID<sup>®</sup>

Bruce E. Logan: 0000-0001-7478-8070

### Notes

Views expressed in this editorial are those of the author and not necessarily the views of the ACS.

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