The Future of U.S. Desalination for Safe Drinking Water

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March 8, 2019

Safe drinking water is an essential human need. But the vast majority of the world's water (e.g., seawater) is high in salinity (briny) and dissolved solids, and is unsuitable for drinking and most domestic uses. (Making it potable cannot be accomplished without extensive and costly treatment compared to conventional treatment of traditional freshwater supplies.) According to the United Nations, water scarcity already affects every continent, especially in (semi)arid and rapidly growing coastal areas. And it's not just California: Freshwater scarcity is already or expected to be a statewide or regional problem in many inland states like Nevada, Montana, and my home state of Colorado.

Banks of reverse osmosis filters in a desalination plant

We've written about water conservation and advanced treatment to produce potable water from highly treated wastewater (water reuse), but this article focuses on the potential role of desalination to help confront our nation's growing freshwater scarcity problems.

"Desalination 101"

> ***What Is Reverse Osmosis?***
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> *Reverse osmosis uses high pressure to push pretreated water through semipermeable membranes, often packed in long tubes. These act like microscopic strainers allowing only water molecules to pass through, leaving behind the salt, minerals, and other impurities such as viruses. These are removed as concentrated brine solution for eventual discharge. The remaining "product water" stream is sent along for further treatment and disinfection.*

In basic terms, desalination is a process that turns briny water—everything from brackish inland groundwater to seawater—into fresh drinking water by removing salt, impurities, and contaminants. Desalination has been around for decades and already provides an alternative water supply in many parts of the world, with an estimated global production of almost 23 billion gallons of treated water per day in 2015. Two technologies are central to large-scale desalination for drinking water: (1) thermal distillation (evaporation), which is still widely used in areas like the Middle East where energy is often cheap or subsidized; and (2) more modern reverse osmosis (membrane separation) technologies that are discussed below.

Before briny water can undergo reverse osmosis, several *pretreatment* processes are needed to remove contaminants that may form as a result of scale formation or through membrane fouling. Such contaminants will interfere with the desalination process. Although pretreatment processes vary from plant-to-plant, they commonly include coagulation and membrane-based microfiltration to remove smaller and smaller particulates as well as organic matter. A disinfectant, commonly chlorine, is often applied during pretreatment to minimize membrane fouling caused by biofilm growth.

Water that has been desalinated requires additional post-treatment before it is ready for distribution and consumption. *Conditioning* is needed to add back alkalinity with some minerals like magnesium and calcium (remineralization), often by blending with a different treated water source (e.g., imported water), to reduce the corrosive nature of the product water[1] on downstream storage and distribution systems. Remineralization also improves the stability and compatibility of desalinated water with blending water. It is also necessary to ensure an adequate level of residual chlorine disinfectant to provide lasting public health protection from waterborne pathogens (disease-causing microorganisms) like viruses that might have passed through the membranes or biofilm-associated bacteria that can colonize the drinking water distribution system.

Current Use and Federal Investment

As part of its Water Security Grand Challenge, the U.S. Department of Energy recently announced plans to invest $100 million in the next five years to establish a desalination research and development hub "as once-periodic water shortages have become perennial, if not ever-present, in American communities, forcing policymakers to rethink how residents get freshwater." This is because desalination remains a comparatively costly and energy intensive enterprise.[2] For comparison, while Israel draws more than half of its freshwater supply from desalination plants (and >85 percent of its municipal water is reused), an estimated 1,330 U.S. desalination plants of all types and sizes currently provide <0.002 percent of the water consumed each year. Becoming operational in late 2015 and considered a success story, the largest U.S. desalination facility is in Carlsbad, California, and provides 50 million gallons of "drought-proof" water each day from the Pacific Ocean to 400,000 residents in San Diego County, supplying 10% of its needs. Some experts hope that the federal infusion of financial resources will help make a major breakthrough in desalination possible in as little as a decade. As in all things, only time will tell, but some desalination-related innovations are bound to also support advances in water reuse technologies and applications.

Opportunities and Obstacles

Growing water scarcity across parts of the United States is happening and driving cost-effective solutions that may also lead to an expansion of inland desalination. For example, the increasing difficulty and costs of obtaining fresh groundwater has narrowed the gap with the price tag for desalination and its potential to treat widespread brackish groundwater. In addition to potential concerns with low levels of disinfection byproducts (given the very high quality of desalinated water), some groups claim that desalination acts as a disincentive to water conservation. One well-documented obstacle to expanded desalination is disposal of vast amounts of concentrated brine streams that are unavoidably co-produced. A 2019 review reported that the world's almost 16,000 desalination plants generate about 900 million barrels of brine waste[3] each day that require appropriate disposal. However, most brine solutions[4] are returned (sometimes diluted) to near-coastal zones and can sometimes be associated with negative environmental impacts, such as reduced dissolved oxygen levels and reports of associated ecological effects.

Over the last several decades, steady advances in conventional treatment of freshwater sources like rivers, lakes, and deep groundwater aquifers have enabled us to maximize their use. However, in areas where readily available freshwater fails to meet our needs, such as some rapidly growing coastal regions, the demand for "creating" new freshwater from saltwater (and water reuse) will only increase. Desalination technologies are poised to benefit from accelerated research

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[1] Desalinated water is corrosive because of its low (acidic) pH and the absence of the absorption potential of carbon-based compounds that are usually found in natural sources of freshwater.

[2] Treated freshwater traditionally costs about 50 cents per cubic meter in an average U.S. market, while desalinated water can cost $2 or more per cubic meter.

[3] On average, for every liter of freshwater produced, desalination plants produce 1.5 liters of brine, but actual plant-specific amounts can vary dramatically based on the salinity of the source water and other factors.

[4] In the United States, other brine disposal methods include regulated injection into deep underground wells and storage in above-ground, lined evaporation ponds.

investments and innovations to make it even more cost effective. So while the future role of U.S. desalination is still evolving, *it does have a significant future*.

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