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Thirsty California Turns to Sea and Sewer

Deirdre Lockwood

Hit by severe drought, the state invests in desalination and wastewater recycling to provide new sources of drinking water.

California is four years into a severe drought, putting reservoirs like Millerton Lake near Friant, Calif., at record-low levels. Credit: Lucy Nicholson/REUTERS/Newscom.

In April, California Governor Jerry Brown ordered the state's first mandatory water restrictions in response to a fourth year of severe drought. The regulations are designed to cut urban water use by 25%—in part by prohibiting the use of potable water to irrigate street medians and lawns on certain types of properties. To meet these requirements, water utilities are encouraging conservation efforts, including offering rebate programs for the installation of low-flow toilets and washing machines, and lawn replacement with drought-tolerant plants.

For water-starved communities, "the most cost effective technology is conservation," says Tzahi Y. Cath, director of the Advanced Water Technology Center at the Colorado School of Mines. But with aquifers and reservoirs running low, and dry conditions predicted to become more common across the state with climate change, many California municipalities are also planning for the future by considering two less conventional sources of drinking water: the sea and the sewer.

Neither desalination nor wastewater recycling is new to California. One of the state's first large desalination plants was built in Santa Barbara in 1991 in response to the region's last major drought, but it only made it into a testing phase before being decommissioned when rains returned. Now the city plans to update it and put it back in service, at a cost of $40 million. Meanwhile San Diego County is building a new desalination plant in Carlsbad for $1 billion. When it opens in late 2015, it will provide 50 million gallons of water a day to the county, making it the largest in the United States. As for wastewater recycling, the largest plant of its kind in the world is the Orange County Water District's Groundwater Replenishment System, which treats sewage wastewater to replenish inland and coastal aquifers. In service since 2008, it can produce 70 million gallons of treated water per day; the water district is now spending $143 million to expand it to yield a total of 100 million gallons a day, enough to supply 850,000 residents.

Communities across the state are weighing the costs and benefits of the two approaches as they debate whether to follow in the footsteps of Orange County or San Diego. For coastal communities, desalination promises a reliable water source, but it is still extremely expensive and energy intensive, which is problematic in a state committed to reducing its expenditures and greenhouse gas emissions. Environmentalists are also concerned that the process can harm coastal ecosystems. In contrast, recycling wastewater into drinking water is cheaper and may have a smaller environmental impact, but it raises an "ick" factor for some people and poses health concerns about exposure to pathogens and micropollutants.

In current state-of-the-art facilities, the linchpin of both approaches is a water purification method called reverse osmosis. It involves using pressure to force water through a semipermeable membrane, producing freshwater on one side and leaving concentrated brine behind on the other. But because the energy requirements of reverse osmosis are proportional to the salinity of the water to be treated, desalination is about twice as energy intensive—and expensive—as wastewater recycling.

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When the desalination plant opens in Carlsbad, it will pump 100 million gallons of seawater per day through its systems. It will screen and filter that water to remove particulates, and put the water through reverse osmosis. After further drinking water treatment, the recovered freshwater—50 million gallons per day—will be pumped through a pipeline to surrounding communities, and an equal volume of the salty brine that's left behind will be returned to the ocean.

Thanks to advances in reverse osmosis, new desalination plants, such as the one in Carlsbad, will use about 80% less energy than ones did 30 years ago. New thin-film composite membranes process water more efficiently and can be more easily cleaned to prevent fouling. Current plants now include better pumps and energy recovery methods, so that their efficiency approaches the thermodynamic limit, says Menachem Elimelech, director of the environmental engineering program at Yale University. They use about as much energy as it takes to pump water from the northern part of California over the Tehachapi Mountains to Los Angeles, says David L. Sedlak, an environmental engineer at University of California, Berkeley. Following Carlsbad's lead, more than a dozen other coastal communities in California have proposed plants. But it is a hotly debated issue.

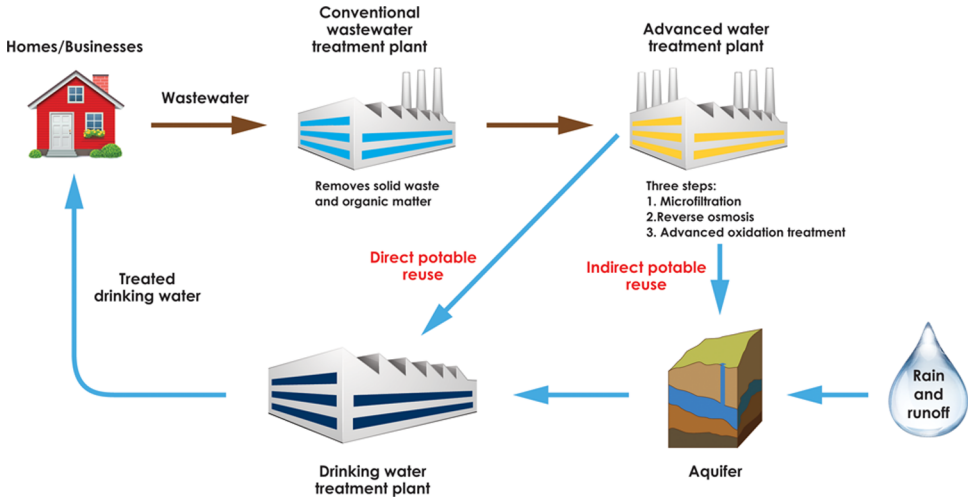
In the environmentally conscious Golden State, many still think the downsides of producing freshwater from the ocean are too great. Despite their improvements, the plants are still a large source of greenhouse gases. Although integrating solar or wind power into proposed projects helps this issue, Sedlak says, it also raises the cost.

Environmentalists are also concerned about desalination's impact on coastal ecosystems. Fish and other marine organisms can be sucked into the intake pipes. And the brine left behind after freshwater is harvested gets pumped back into the ocean on the seafloor, where it could harm bottom dwellers.

Proper design can mitigate these issues, experts say. For example, situating intake pipes below the seafloor minimizes the entrainment of marine life, and the brine outflow can be dispersed over a large area or diluted with treated wastewater to reduce harmful effects. In May, the California State Water Resources Control Board approved a desalination amendment that would require future projects to be designed with the best available measures to mitigate ecological damage; it would also limit the salinity of discharged brine and require monitoring of the discharge and the health of bottom-dwelling organisms.

Finally, investing in a desalination plant is an expensive financial gamble. During Australia's recent drought, Sedlak points out, many major cities on the continent built desalination plants, at a cost of about $1 billion each. But now that rains have returned to most of the country, many of them have been mothballed. Because desalination plants are so expensive to run, Sedlak says, "the minute the rain starts up, they're going to go idle and be a stranded investment." Elimelech agrees, saying seawater desalination should be the "option of last resort" as a source of drinking water.

So that leaves wastewater recycling as, ironically, the more palatable option. In Orange County, wastewater first goes through a conventional treatment plant. Then the recycling plant passes that treated wastewater through a three-step



Wastewater from homes and businesses that is destined for recycling can follow two basic paths: direct or indirect potable reuse. For both, the wastewater first travels through two treatment plants that purify the water. For indirect potable reuse, this purified water gets pumped into aquifers, where it mixes with rain and runoff. Municipalities then pump water from these aquifers into a drinking water treatment plant to produce tap water. For direct potable reuse, the purified water goes straight to a drinking water treatment plant. Credit: C&EN/Shutterstock.

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process: microfiltration to strain out suspended solids, reverse osmosis to produce freshwater, and finally advanced oxidation treatment with ultraviolet light and hydrogen peroxide to remove low-molecular-weight compounds that can make it through the reverse osmosis membrane. The water is then pumped into aquifers, where it can spend months to years mixing with the groundwater and runoff that percolates in. When this water is pumped out of the aquifer, it goes through a water treatment plant before it's delivered to residents' taps. The water exceeds state and federal drinking water standards, at a cost lower than importing water from northern California and the Colorado River.

According to Sedlak, when other water districts began exploring building similar plants during the drought of the late 1980s and 1990s, they encountered a skeptical public. To many, the idea of drinking water that started out as sewage was unfamiliar and off-putting, raising concerns that it would taste bad or pose health risks. Opponents coined the phrase "toilet to tap" to criticize the idea, and it has stuck.

"It's a new world for water utilities," Sedlak says. "For a new technology like wastewater recycling, you have to pay attention to whether the community accepts it as a legitimate approach." He says that California water utilities that have succeeded in implementing similar systems to Orange County's—including the West Basin Municipal Water District near Los Angeles and the Inland Empire Utilities Agency in San Bernardino County—have taken a proactive approach by regularly testing water to make sure it meets drinking water standards, keeping up with the latest water quality research, and sending managers out to the community to listen to people's concerns.

There are two major health concerns when it comes to recycling wastewater into potable water, Sedlak says. The first is the possibility of a catastrophic failure of the system that could expose people to water-borne pathogens. To prepare for this risk, water utilities develop online monitoring systems and build in fail-safe mechanisms to stop tainted water from reaching aquifers, he says.

The second is the potential for long-term exposure to trace amounts of chemicals that can make it through the treatment process. These contaminants include pesticides, pharmaceuticals, and endocrine disruptors. These compounds, many of which are not yet regulated, are generally present at concentrations of only parts per billion in treated water, but they can have both human health effects and environmental impacts.

Nancy D. Denslow, a biochemist at the University of Florida, recommended new techniques to screen for these compounds when she served on scientific advisory panels for the California State Water Resources Control Board from 2009 to 2012. For example, she and other panelists recommended using cell-based assays to test water for the presence of certain chemical classes of concern, including estrogens, androgens, progestins, growth hormones, and polycyclic aromatic hydrocarbons. The assays are commercially available through Invitrogen and would be easy for water utility technicians to perform and analyze with a spectrophotometer, Denslow says.

"This is a problem that will probably stay with us for many years," says Colorado School of Mines's Cath, because current plant designs cannot remove some of these emerging contaminants. Removal methods, though, do exist, for example, by using hybrid processes that combine nanofiltration with reverse osmosis and advanced disinfection, or approaches that combine several membranes. But then the cost of wastewater recycling would approach that of desalination, Cath says.

Still, the levels of these emerging contaminants in recycled wastewater are similar to those in much of the U.S. water supply, Sedlak says, as many cities source their drinking water from rivers that receive wastewater effluent or industrial or agricultural discharge.

Taking wastewater recycling one step further, some water researchers and agencies are proposing to bring down water treatment costs by bypassing the intermediate step of putting treated wastewater underground in an aquifer, as Orange County does. Instead, after undergoing advanced treatment, the water would be introduced directly into a drinking water treatment plant or distribution system for delivery to users. This strategy is often called direct potable reuse. It has been done in Namibia, and Texas has recently completed two such projects. Sedlak recently served on a California state panel to assess a possible regulatory framework for the approach. "Most people are convinced that the technology exists," he says. "We just need to make sure it's done in a way that is safe and reliable."

"From an economic and energy perspective, direct potable reuse makes a lot of sense," says Eric M. V. Hoek, an environmental engineer at University of California, Los Angeles, "but there is a fear of the unknown," particularly the possibility that the approach could introduce harmful chemicals into the water supply that are beyond current limits of detection.

California communities will have to weigh these difficult decisions as the severe drought continues. But one thing managers and residents have going for them, Hoek says, is that the drought has made water issues part of the public

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dialogue. "It's reached a tipping point," he says. "Even if we have a wet year—which I hope we do—I hope it doesn't relieve the pressure and make people feel like the problem is going to take care of itself."

Deirdre Lockwood is a freelance contributor to Chemical & Engineering News, the weekly newsmagazine of the American Chemical Society.

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