SUSTAINABILITY

Bottoms Up

Treated sewage could be the safest, most environmentally sound source of tap water yet—if we can get over the yuck factor

By Olive Heffernan

ON A SUNNY DAY IN DECEMBER, I VISIT A SHINY, STERILE WATER-PROCESSING facility nestled in the hills of northern San Diego. Sheltered by an ugly cream-colored roof but lacking walls, the workings of this oversize chemist's laboratory glisten in the warm winter sun. Visible from every angle are row on row of silver tubes and canisters of various shapes and sizes and great gray metal vats of concealed liquid. As my tour of the small plant comes to a close, I am presented with a challenge: to identify, by sight, the contents of three large glass bottles, spaced evenly on a table before me and filled with clear fluids. The first bottle seems to have a slight yellow hue. The second is colorless. The third has the brilliance of a well-cut diamond.

Photograph by Sam Kaplan

I complete my task with ease, identifying the contents, in order, as regular tap water, recycled wastewater from a conventional treatment plant and highly purified toilet bowl water, produced on-site. I am surprised not just by my overwhelming urge to drink the treated sewage but also that I cannot. "We're not allowed to taste it or to have visitors taste it," says a serious Marsi A. Steirer, my guide and deputy director of the City of San Diego Public Utilities Department, which runs the plant.

That could soon change. A six-year pilot project overseen by Steirer and completed in 2013 at this Advanced Water Purification Facility, or AWPF, showed that purified sewage from residential buildings is not only cleaner than existing drinking water, it can be produced at less cost than other options for creating freshwater, such as desalination. For San Diego, the process could be revolutionary, if and when state regulators sanction it.

San Diego imports as much as 90 percent of its water from the Colorado River to the east and the Sacramento–San Joaquin River Delta to the north. But both those sources are running dry. The price of imported water will double in the next decade. By converting effluent, San Diego could meet 40 percent of its daily water demands. And it would put an end to the city dumping poorly treated wastewater into the ocean.

But let's face it, not everyone wants a mouthful of treated sewage. This "yuck factor" quashed an attempt in the late 1990s to start a similar scheme in San Diego, and a poll in 2004 found that 63 percent of residents still opposed the idea of reuse. Numerous proposals in Australia have met the same fate, vetoed by vocal civic groups. Laurence Jones, who had founded one Australian group, Citizens Against Drinking Sewage, questions whether sewage sourced from hospitals, industry, homes and slaughterhouses can ever be fully cleaned. "What we know is that the sewage effluent is 100 percent contaminated," he says.

Attitudes in San Diego have undergone an amazing turnaround, however, as drought has worsened and coastal neighborhoods have grown. Now nearly three quarters of the population are in favor of treated toilet water, but with one stipulation: that after the effluent is cleaned, it will be sent back to a reservoir, where it can be highly diluted and then treated further before being piped to homes.

That process is known as indirect potable reuse. The people running the AWPF plant, currently a test site for this approach, hope to take an additional step: treat effluent to a high level of purity and send it straight to the tap—known as direct potable reuse. For many residents, though, that last step goes too far. "It just seems more palatable to put the water back into a reservoir," says Megan Baehrens, executive director of San Diego Coastkeeper, a nonprofit organization that played a key role in persuading the city to launch the project.

Which process wins will determine what California regulators will allow San Diego, and the rest of the state, to do. And if direct reuse is sanctioned here, where environmental regulations are notoriously rigid, experts say the process will soon spread to other drought-afflicted communities worldwide. "California tends to influence environmental decisions globally," says international water expert Shane Snyder of the University of Arizona, "and it will do the same with wastewater treatment."

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THE CLEANER THE BETTER

ALL EYES ARE INDEED on the San Diego pilot facility. Right now the plant produces one million gallons of water a day. Although the water is purified to drinking standards, it is sent to irrigate the nearby Torrey Pines Golf Course and a cemetery. Steirer wants to scale up to 10 times the current capacity in the next five to 10 years. The default plan is to release the treated water into the local San Vicente Reservoir to dilute it, after which the mix of treated and reservoir water would be sanitized and sent to homes. Plan B—if regulators allow it—will be the direct approach.

Regulation will not be enough, however, for either approach to gain the public's nod. The utility must get consumers past the yuck factor. Critically, it must convince people that the water is clean. More than 4,000 visitors have toured the plant, among them mothers, Girl Scouts, doctors and elected officials. Many of them question the safety of consuming what was once raw sewage. It is not a trivial concern. Every year 19 million Americans become sick, and 900 of them die, from viruses, bacteria and parasites in water that has undergone the routine treatment that most municipalities use.

One way to win hearts and minds is to make sure the resulting water is purer than current water supplies are. On the tour, visitors learn that purified effluent is, ironically, much cleaner than their tap water is now. That is because most of us are drinking "downstream"—the river or lake that supplies our tap water doubles as a disposal site for water coming from standard sewage treatment plants, which is not clean enough to drink. "Water in the Mississippi River has been used five times by the time it reaches New Orleans," explains George Tchobanoglous, an international water expert at the University of California, Davis. Yet people expect water that will come from effluent to be held to a much higher standard than regular municipal supplies are.

Steirer says the purified wastewater in San Diego is indeed "much cleaner" than water that comes from a typical drinking-water treatment plant. Furthermore, storing water for such a

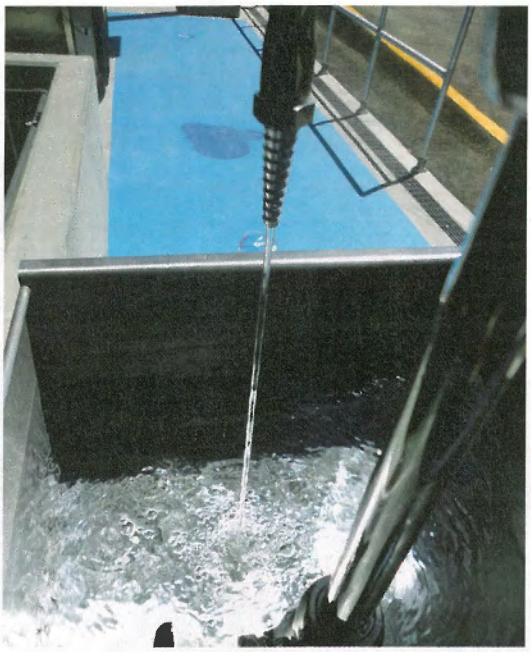
IN BRIEF

Drinking water is getting scarce and expensive for communities worldwide. New multistep purification processes could help solve the problem by converting wastewater into clean tap water.

San Diego has developed a state-of-the-art purification system. If regulators allow it to send treated sewage directly to the tap, the operation could set the standard for many cities and countries.

The biggest hurdle, however, is persuading the public to overcome its reluctance to drink treated wastewater, even when it is proven to be cleaner than what residents drink today.

PAGE 68: STYLING BY LINDA KEIL *Halley Resources*



REVERSE OSMOSIS, done in long white cylinders (*above left*), removes salts and microscopic impurities from one million gallons of wastewater a day at the San Diego Advanced Water Purification Facility. The final product is almost as pure as distilled water.

plant in a reservoir or an aquifer carries its own risks, says David Sedlak, engineering professor at U.C. Berkeley. Ducks and other animals introduce filth into reservoirs, for example, and arsenic can leach from rocks into groundwater. "Some people argue we should cut that risk by going direct," he explains.

Traditional treatment for U.S. drinking water goes through two or three steps for removing suspended solids and is then disinfected using chlorine. Transforming fragrant sewage into pristine tap water requires different engineering. The AWPF plant takes sewage water treated by the North City Water Reclamation Plant and adds higher levels of cleansing to "purify" it.

The first step at the AWPF is microfiltration, which happens in large tubes that resemble giant drums of pasta [*see box on pages 72 and 73*]. Shane Trussell, president of Trussell Technologies and head of engineering at the project, tells me that each drum contains 9,000 of these pastalike fibers and that each fiber is dotted with microscopic pores 300 times as narrow as a human hair. As water is forced through the tubes, the fibers filter out viruses, bacteria, protozoa and suspended solids.

Next, the water is sent at high pressure through tubes with even smaller fibers, in a process known as reverse osmosis. This step removes any remaining dissolved particles, up to 10,000 times as small as even the tiniest bacteria, including chemicals, viruses and pharmaceuticals. For the final step, water at the AWPF goes to advanced oxidation, where it is mixed in huge vats with minute amounts of highly concentrated hydrogen peroxide and then exposed to ultraviolet light. This stage destroys any remnant contaminants, even at quantities of parts per trillion, a dose equivalent to a single drop in hundreds of Olympic swimming pools.

Of the one million gallons of wastewater entering the plant daily, 80 percent makes it through to final approval—it is as pure as premium-grade bottled brands. It could be sent to the San Vicente Reservoir if the plant had a permit for indirect reuse. As it stands, the water goes into the state's purple pipes, seen alongside certain roads, which supply the region with recycled water for irrigation and industry. The remaining 20 percent is sent to the local sewage treatment facility for disposal. Some of the substances that regularly turn up in the purified water are caffeine, hand cleaner and artificial sweetener, but they are in such minute doses as to be harmless, Trussell says. The final product is also extremely low in salt—20 parts per million (ppm), compared with 600 ppm in the city's imported water.

This past April, Trussell and his band of engineers added yet another step to make the water clearer and cleaner still. The purified water would be exposed to ozone, which would raise the removal of microbes, for example, to 99.9999 percent. The water would then go through specialized filters meant to further reduce any organic content. If successful, this single addition could be enough to convince regulators that there is no need to send the treated water to a reservoir. "We can never say that we've removed every pathogen from the water," Trussell says. Yet the water quality would far exceed all state and federal drinking-water standards; in fact, the purified water that was produced before this latest add-on step already met or exceeded those standards.

PSYCHOLOGICAL ADVANTAGE

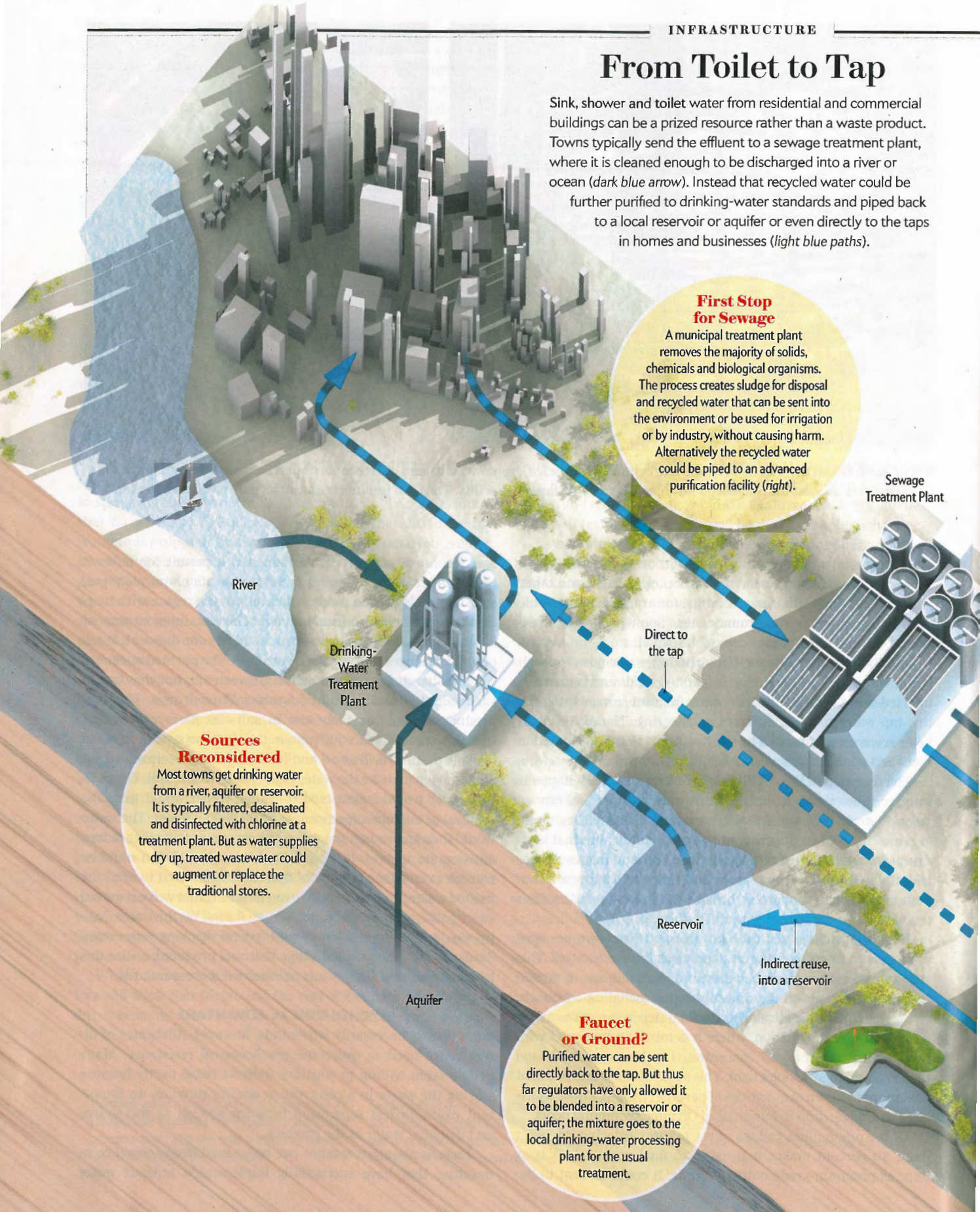
FACTS DO NOT necessarily win minds, however. Advocates of direct reuse need to overcome psychological resistance. Many people seem willing to consider indirect reuse partly because storing the water in a reservoir or aquifer provides an important psychological separation between sewage as the source and drinking water as the product.

Lessons about acceptance can be learned from several communities that have successfully implemented indirect water

COURTESY OF THE CITY OF SAN DIEGO

From Toilet to Tap

Sink, shower and toilet water from residential and commercial buildings can be a prized resource rather than a waste product. Towns typically send the effluent to a sewage treatment plant, where it is cleaned enough to be discharged into a river or ocean (*dark blue arrow*). Instead that recycled water could be further purified to drinking-water standards and piped back to a local reservoir or aquifer or even directly to the taps in homes and businesses (*light blue paths*).



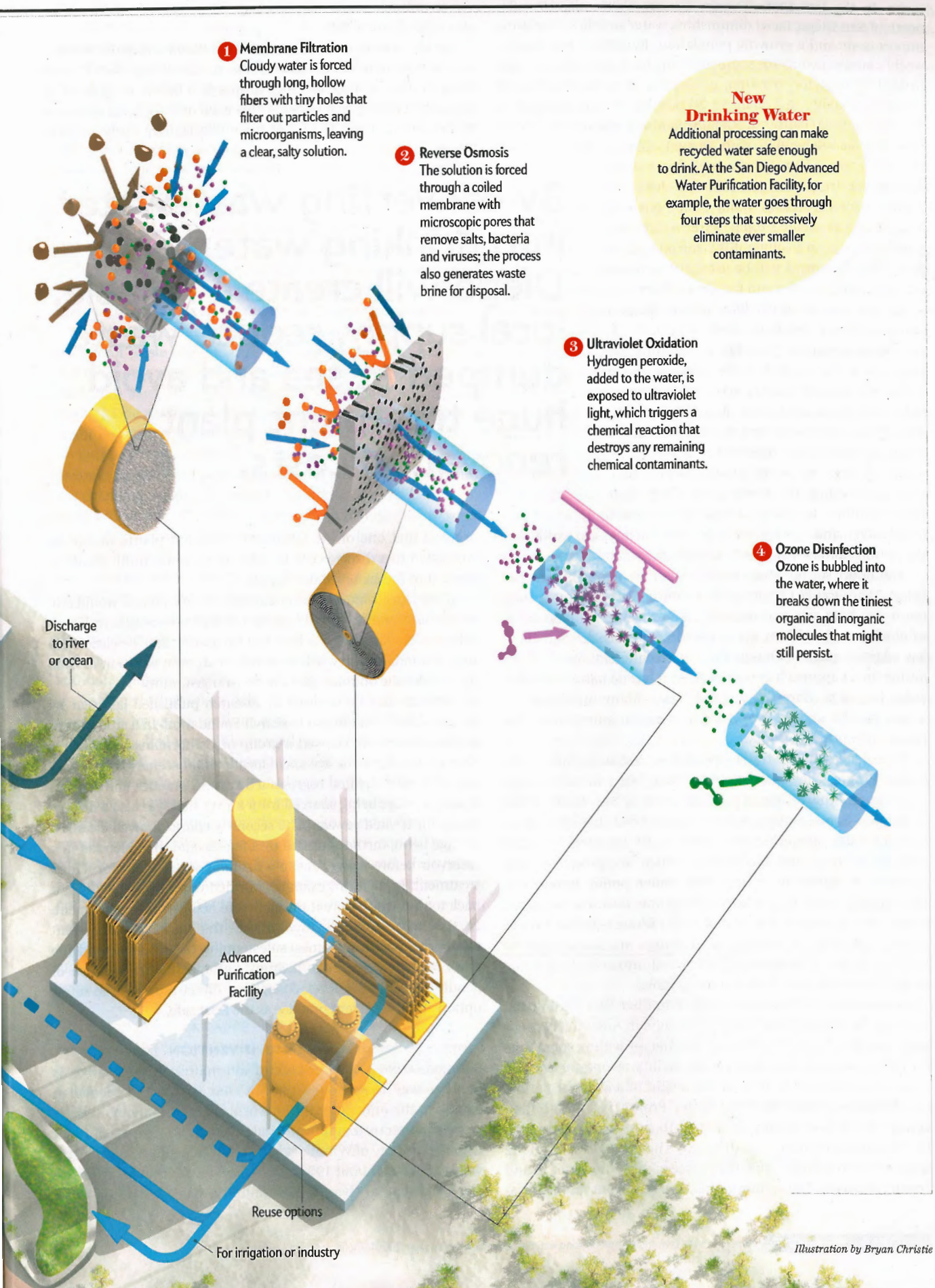


Illustration by Bryan Christie

reuse. In the late 1990s Orange County, California, 90 miles north of San Diego, faced diminishing water supplies, escalating import costs and a growing population. By 2008 it boasted the world's largest facility for supplementing local groundwater with treated effluent for drinking, processing 70 million gallons of wastewater daily, equivalent to 20 percent of local demand. A few other municipalities in California also drink tap water that has been supplemented with treated effluent but to a lesser extent. An advanced $68-million wastewater treatment plant in San Jose, designed to supply Silicon Valley with eight million gallons of treated toilet water a day, was scheduled to start in June; it is clean enough to drink, but for now it will be used just to water farms and golf courses and for local industry.

At the outset—much like in San Diego—Orange County residents were skeptical; 70 percent opposed the plan. But by the time the plant came online, it had the backing of the entire community, thanks to a very effective public relations campaign. Ron Wildermuth, who led the effort, explains that staff members of the county's water district had seven years' worth of data on water quality before they even approached the community. They then spent another 10 years talking to everyone from rotary and garden clubs to local businesses, explaining the options and inviting them to taste the water.

The effort set the stage for what is now happening in San Diego. "The Orange County project showed that indirect potable reuse was both safe and feasible," Steirer says. "Without it, we wouldn't even be talking about the direct approach." San Diego has adapted much of Orange County's technology, too. It hopes for the direct approach in part because it has no natural groundwater basins to store the purified water. Many municipalities across the U.S. and the world are in a similar situation, so San Diego is the proving ground.

Experiences in Australia reveal how *not* to influence the public. Progress has been "disappointing," says water management expert Stuart Khan of the University of New South Wales in Sydney. Some provinces have banned the drinking of reclaimed water altogether, and water reuse schemes for cities such as Brisbane and Melbourne—which are prone to long, sporadic droughts—have imploded under public opposition. The mistake made by the government was pushing for public acceptance at exactly the wrong time, Khan believes. "We've learned the folly of waiting until things are desperate," he laments, meaning that people felt forced into accepting something with which they were uncomfortable.

It is best to start the conversation early, Khan says, adding that now may be an opportune time to try again in Australia because water supplies have rebounded somewhat, providing some time for discussion with the public. One facility is ripe for conversion. Commissioned in 2006 at the height of a drought period, the Western Corridor Recycled Water Project is a $2.3-billion system that was originally developed to supply recycled water for industry, agriculture and drinking. The plan was to send the water to the Wivenhoe Dam, the source of most tap water in and around Brisbane. The system gathers effluent from six wastewater treatment plants and sends it for advanced treatment at three cleansing plants.

As the system came online between 2008 and 2010, however, the drought ended, and plans to drink the water were shelved until storage supplies dropped to below 40 percent of capacity. The recycled water is now used only for local industrial processes. Khan is one of many Australian water experts arguing that one of the advanced treatment plants should be converted to a direct reuse facility, which could fulfill about 35 percent of Brisbane's water supply.

By converting wastewater into drinking water, San Diego will create a reliable, local supply, reduce waste dumped at sea and avoid huge treatment plant renovation costs.

If the Queensland government opts for this plan, it would create the largest direct potable reuse facility in the Southern Hemisphere. Convincing politicians and the public may be easier this time around, but they will need information in addition to time to consider the options—just like in Orange County.

Officials may be inspired by research published last year by the U.S.-based WateReuse Research Foundation. In a study, foundation researchers showed a group of Californians and Australians of mixed gender, age and education four scenarios for sourcing tap water. The first represented current practice and showed drinking water being sourced from a river that was also a disposal site for treated sewage. The second scenario showed cleansed sewage being further purified by a facility and then blended in a reservoir before being sent to a drinking-water plant for added treatment. In the third example, purified water was sent straight back to the river, where it mixed before being sent for treatment. In the final scenario—direct reuse—the purified water went straight to the city's homes, sidestepping the reservoir and the additional treatment plant. Study participants, irrespective of gender or education level, considered direct reuse as the safest option and the current practice as the least safe.

NECESSITY AS INVENTION

DEMONSTRATING AN UTTER LACK of alternative water sources is another way to sway the public. That is what succeeded in Namibia, the only place in the world that is supplying directly recycled water on a significant scale. Back in 1957, severe drought depleted the city of Windhoek's groundwater supply in just eight weeks. Located about 190 miles inland and 500 miles from the closest perennial river, the community was left with no other

SCIENTIFIC AMERICAN ONLINE More on how to save and cleanse drinking water at ScientificAmerican.com/jul2014/heffernan

reliable water source. By 1968 the city had a fully operational direct reuse facility. Today 25 percent of Windhoek's tap water comes from processed sewage.

Windhoek faced fewer public challenges than San Diego does. For a start, "there was no activism back then," says Petrus du Pisani, who oversees the facility. "Citizens may have been a little wary, but they accepted the necessity of the decision." Back in the late 1960s, he notes "people had a lot of faith in science and officialdom." Still, the city informed locals and invited them to taste the water. "Now, for us," du Pisani says, "drinking recycled water is just accepted practice."

The system in Namibia would never fly elsewhere today, however. Although it uses multiple treatment steps, it does not include reverse osmosis, key to the San Diego project and others such as Orange County. Officials in Namibia say the water is safe and meets standards set by the World Health Organization.

Windhoek, located inland, could not easily dispose of the large volume of waste brine that reverse osmosis creates. And in the 1960s "there were fewer man-made chemicals" in the wastewater, du Pisani says. "Our main concerns were soaps and frothing agents." One downside of omitting this step is that the drinking water is high in total dissolved solids, which makes it taste salty.

Du Pisani says Windhoek will probably add small-scale reverse osmosis by 2020 to reduce saltiness. Drinking-water standards are changing rapidly throughout the world, even in Namibia, he adds, noting that Windhoek's approach is no longer the most appropriate. The volume of brine, as well as the large amount of energy needed for reverse osmosis, could make direct potable reuse too costly for other communities. Ironically, new treatments are being developed that could reduce the amount of brine, and waste in general, from the overall process. Indirect reuse and desalination can both use reverse osmosis, too. Direct reuse is thus often less energy-intensive than those options because they require additional pipelines and energy to push water through them.

As drought has taken hold in the U.S., several communities have been forced to confront a fate similar to Windhoek's. Big Spring, Tex., had seen little rainfall, year after year. Cloudcroft, N.M., a small mountain community that more than doubles in size on weekends and holidays, had been hauling water over considerable distances. In the past year both towns have begun to purify effluent to supplement their drinking water. Neither community boasts a suitable reservoir or aquifer for storing the treated water over the long term. Instead in Cloudcroft, the purified wastewater is blended with water taken from a local well or spring and stored temporarily in a holding tank before being treated again and piped to people's homes. In Big Spring, the cleansed wastewater is mixed with water from a distant, regional reservoir, and the mixture is treated. The approaches evade classification; some say they are direct reuse, and others call them indirect.

A TASTE FOR SUCCESS

SAN DIEGO IS NOT IN such dire straits yet, which causes some experts to say the city should consider alternative solutions. Although "a big fan of the concept," water authority and Pacific Institute president Peter Gleick thinks that direct reuse is still decades away from happening in California. "There's no sense of urgency to use reclaimed water," he says. Gleick argues that California should instead focus on conserving water, both in cities and, even more so, in agricultural operations, which use 80 percent of the state's water supply. But Baehrens thinks that San Diegans are already pretty mindful of how they use water: "We don't stay in the shower for long, and we only water our plants in the cool hours of early morning and evening." Part of the problem with water conservation, Steirer adds, is that it is usually voluntary and therefore hard to rely on for planning.

Being prepared with wastewater technology might be prudent. Singapore opened its first NEWater facility in 2000. It now has four of the plants, which are well known for producing the most purified effluent on the planet. Less than 5 percent or so of this water is used for drinking, and it is first blended with water in local reservoirs. The rest is used by industry. Should relations deteriorate with neighboring Malaysia, where 40 percent of its water comes from, however, Singapore could send more of the NEWater supply to the city's taps.

Some communities might worry that cleaning wastewater could be costly. Studies of San Diego indicate that indirect reuse processing at a facility that took in 15 million gallons a day would cost about $2,000 per acre-foot of clean water produced, roughly the same cost as water the city imports now. Studies of direct use processing plants that operate at the advanced level of AWPF show a cost of $700 to $1,200 per acre-foot. Operators of the Poseidon desalination plant now under construction in nearby Carlsbad, Calif., estimate a cost of $1,876 to $2,097 per acre-foot, although independent estimates for desalination in California are $2,000 to $3,000 or more.

Whether the AWPF plant is given a green light for direct or indirect reuse, it is a win for San Diego because it will be a reliable local supply of water, it will reduce waste dumped at sea and it will avoid the billions of dollars needed to upgrade the wastewater treatment plant. Until then, cleansed (but not purified) water will continue to run in the purple pipes that line the roads leading to industries. The pipes are marked clearly with signs that read, "Do not drink."

The city has an opportunity to lead the world in a major rethinking of how we see—and use—wastewater. "Water is a recoverable resource, not a source of waste," Tchobanoglous says. Once that is realized, "municipalities will become like private entrepreneurs and try to recover it." It could be a decade before California has laws on the books allowing direct reuse and before San Diego is able to send a premium-grade product directly to the tap. "We'd love to drink the water and for people to taste it," says Steirer, who looks forward to finally having a glass. SA

MORE TO EXPLORE

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