Saline Solutions: The Quest for Fresh Water

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Desert oasis. A desalination plant in Yanbu, Saudi Arabia.

Half a century of rapid growth has transformed Jeddah, Saudi Arabia, from a walled city of 30,000 people into one of the largest and busiest metropolitan areas in the Middle East. Stretching for 50 miles along the Red Sea, it is a major port for Saudi oil and for Muslim pilgrims journeying to Makkah and Madinah. As such, the city boasts a thriving economy, and its population has swelled to over 1.5 million.

What is unique about Jeddah, however, is not how quickly it has grown but that this large city exists at all in an area so devoid of fresh water. There are simply no rivers or lakes near Jeddah, and its small underground aquifers were not sufficient to support the population 50 years ago. There is no excess water elsewhere in Saudi Arabia that could be shipped to Jeddah, and getting water from abroad is not an appealing solution in the politically tumultuous Middle East.

Faced with such scarcity, Jeddah's salvation has been its ability to transform saltwater from the Red Sea into potable fresh water. Jeddah's five desalting plants produce the vast majority of the city's water—around 105 million gallons of water per day—and more desalination projects are planned.

Water scarcity is the driving force behind the rising cost of conventional water sources, forcing municipalities to look farther and farther away to find streams and lakes to sustain them. For instance, over 400 miles of aqueduct have been built to supply water to Southern California. At the same time, technological advances have made desalination processes more efficient and thus more affordable. But for most of the developing world, where one in three people lacks access to safe drinking water, large desalination plants remain prohibitively expensive.

Based on figures from the World Resources Institute and the International Desalination Association (IDA), worldwide desalting capacity currently stands at about 13 million cubic meters per day, less than 0.15% of the fresh water consumed by human activities. Nonetheless, that capacity represents a 200% increase over the desalination capacity in 1980, with more large commercial plants currently being built.

However, despite steady advances in the technology, desalination remains one of the most expensive ways to produce potable water. In Jeddah, water costs $4–6 per 1,000 gallons to produce, compared to about $1 for water from nonsaline sources in most parts of the world. However, says Jim Birkett, a veteran consultant on desalination projects who serves on the board of directors of the IDA, "Given the circumstances, desalination was really Jeddah's best choice. Desalination gave them water security, and they are able to afford it because of their oil [resources]."

Still, the cost of developing new conventional water resources has been rising in many areas, and during the past 20 or 30 years, the cost of desalination has steadily gone down, Birkett says. "In some communities around the world, like Jeddah, the two costs have crossed each other. In other communities they haven't crossed yet, but you can project them out and see that this is something that we should keep an eye on," he says.

Better Technologies

In 1961, John F. Kennedy remarked that if humanity could find a way to cheaply extract fresh water from the oceans, that feat "would really dwarf any other scientific accomplishments." Many have envisioned desalination plants effectively unlocking the ocean reservoirs that hold 97% of the earth's water and ending water scarcity everywhere. Although that lofty goal will not be achieved in the near future, scientists are developing innovations that may soon make desalination a reasonable option for many more communities.

In Florida, for example, small desalination facilities have been built for many years to supply water to remote resort communities. In these applications, the cost to the consumer is not a barrier, and some Florida residents pay over $10 per 1,000 gallons for water, according to a survey conducted by Leitner and Associates of Boca Raton.

However, as desalination facilities have become less expensive to build and operate, they have found applications outside resorts. In Tampa Bay, where overpumping of groundwater has begun to threaten nearby wetlands, the city recently awarded a contract to a consortium of desalination companies to build a plant that will purify 22.5 million gallons of saltwater per day for the municipal water system. The cost of water from the plant will be around $2 per 1,000 gallons over the next 30 years, a price that's closer to the average cost of groundwater sources in Florida—about $1 per 1,000 gallons. "There are some circumstances that are peculiar to Tampa Bay and reasons why you couldn't take that price and replicate it in other parts of the world," says Birkett. "But this was a real bid, and it shows that in some areas, desalination is becoming competitive."

In Tampa Bay, desalination will be accomplished with membrane systems, the newest approach to desalting. In reverse osmosis membrane systems, which are the most popular, pressure is used to force water through membranes that are less permeable by dissolved salts. This divides the water into two streams—the product water that passes through the membrane and the high-salt brine that is left behind. Other membrane systems, called electrodialysis systems, separate salt ions from water by using an electric charge to pull them through the membranes.

The groundwork for reverse osmosis ystems and other membrane technologies was largely laid by the U.S. Office of Saline Water and its successor, the U.S. Office of Water Research and Technology, between 1951 and 1981. In 1981, however, Congress cut funding for these programs, and research on desalination membranes moved into the private sector. In 1996, Congress passed funding for the six-year Water Desalination Research and Development Program administered by the U.S. Bureau of Reclamation (USBR), but much of the membrane research taking place in this country remains within companies such as DuPont, Dow FilmTec, and Hydranautics.

Kevin Price, manager of the Desalination Research and Development Program at the USBR, says, "The profit margins [for desalination programs] are so thin that there tends to be little money available for research. But there are a lot of start-up companies out there that truly believe the need is so great for this technology that if they can just make a breakthrough, they can make a bundle."

Currently, research on improving membrane systems is taking place on two fronts. On the first, the USBR and private companies are working to develop new membranes that can separate water from salt more efficiently and under less pressure. Price says the USBR is currently funding programs to bring molecular modeling tools developed for the pharmaceutical industry into use for designing new membranes. "There is some of this going on in private companies as well," Price says, "but it's very proprietary so you never see anything in the literature about it."

On the second front, some companies are finding ways to boost the performance of membranes currently in use by reducing the rate at which mineral and biological deposits form on them (thereby preventing water from passing through the membrane). Traditionally, toxic chemicals such as chlorine, hydrogen peroxide, and sulfuric acid have been added to the feed water to prevent biologic fouling and metal scaling. Although the chemicals do not pass through the membrane and thus don't pose a contamination risk for the product water, they become concentrated in the brine and may pose a disposal problem. Although isposal of brine in the ocean is not generally thought to present a serious environmental risk, it can cause problems for inland desalination plants that extract feed water from saline wells. Often, the brine from these plants is injected into other underground aquifers where the water is kept sealed away from any freshwater sources, although this process is a fairly expensive disposal technique.

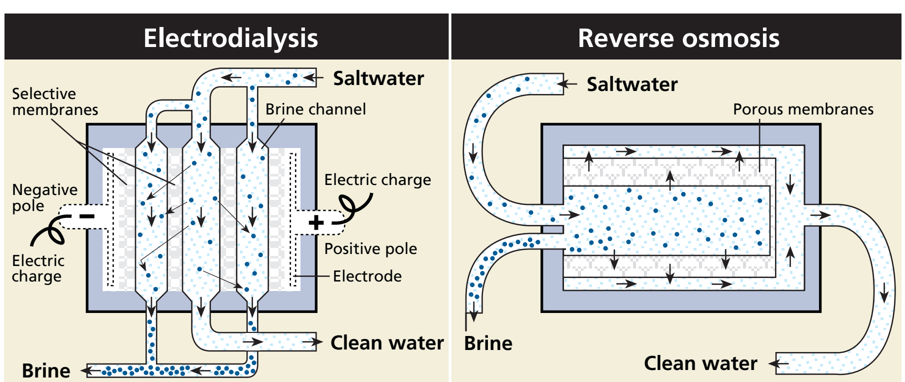
David Furukawa, president of Separation Consultants in Poway, California, says that recent advances could change this. Mineral Water Development International, a company based in Stellenbosch, South Africa, is testing a system that uses flow distributors in concert with electromagnetic fields to greatly increase the efficiency of reverse osmosis. "The [system] inhibits the formation of carbonate scales so you don't need acid. [And] it appears to deter biologic fouling on the membrane so you don't need fouling inhibitors," Furukawa says. "Once you eliminate the need for chemicals in the system, then the concentrate of brine is more easily disposed."

Though Mineral Water Development International has not made data on the system available for review, Birkett says that many in the industry are excited about it. "You have to be skeptical when looking at claims like these," he says, "but this approach looks like it may [be promising]."

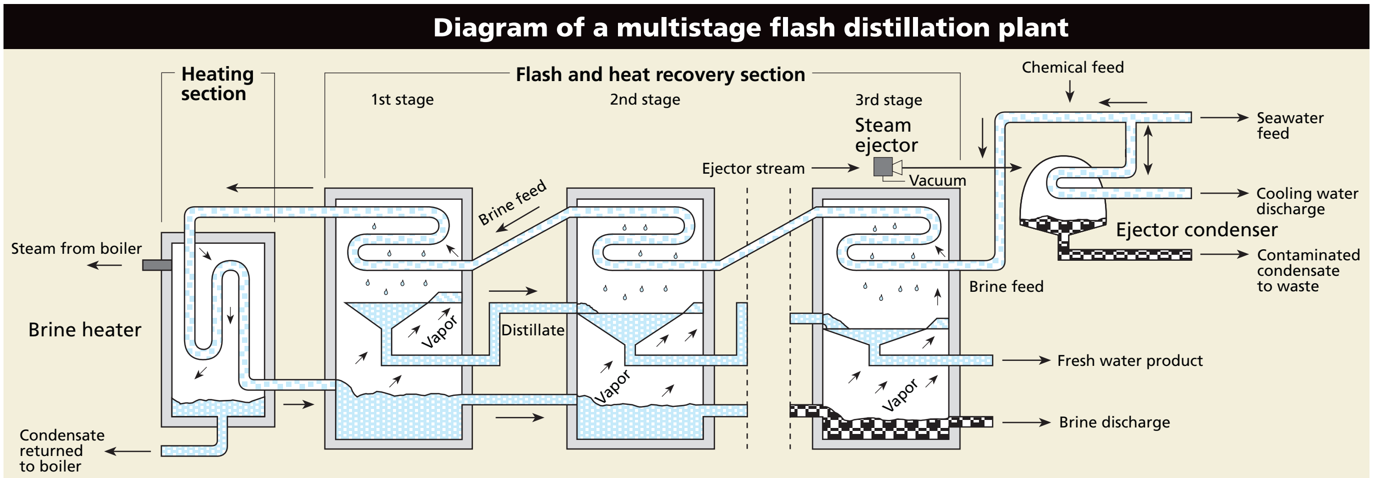
New Life for an Old Process

In Jeddah and most other places, very little desalting is accomplished with membranes. Instead, plants use distillation, the oldest and best-established method for purifying salty water. According to the IDA, distillation plants currently account for 64% of the world's desalination capacity.

Distillation processes use heat and pressure changes to vaporize seawater, thus liberating it of its dissolved and suspended solids. Modern distillation plants like those found in Jeddah primarily use multistage



Good enough to drink. Two of the most popular methods of desalination use high-tech membranes to filter the salt from seawater to make potable water. Source: International Desalination Association, http://www.ida.bm/.



Tried and true method. Modern distillation plants use systems in which heat and pressure are used to separate seawater into fresh water and brine.
Source: International Desalination Association, http://www.ida.bm/.

flash evaporators. In these systems, feed water is heated and then sent into a series of chambers or stages, each maintained at a lower internal pressure than the previous one. Because the boiling point of water decreases as pressure decreases, evaporation is achieved in each chamber without more heat being added. However, these plants still require the feed water to be heated to 90–120°C in the initial stage, which requires a sizable energy input.

In countries such as Saudi Arabia, where energy is cheap, this is not a serious obstacle. Furthermore, most distillation plants in the Middle East and North Africa use the waste heat from electric power plants to heat the feed water. "If you have a 10-megawatt steam turbine station," explains Birkett, "you can quite comfortably couple that with a distillation plant to make a million gallons a day of fresh water. That ratio, 10 megawatts to 1 million gallons per day, happens to be quite close to a common demand ratio in these communities." This cogeneration design particularly makes sense in places such as Jeddah, where water and electric infrastructures were being built simultaneously.

Other efforts are being made to combine membrane and distillation systems to improve their efficiency and reduce the need for chemical treatment of the feed water. For example, filtration similar to reverse osmosis is being tested as a pretreatment for distillation plants to reduce scaling and fouling.

Until very effective methods have been established to remove impurities from seawater, the cost of desalination systems will remain largely dependent on the quality of the feed water. "The cost of desalination is very site-specific," says Price. "Depending on what's in your water, you may have to do a lot of pretreatment, which can get expensive."

Desalting Wastewater

Research over the past 10 years has shown that membrane desalination systems can also be applied to the effluent from wastewater treatment plants to produce water that is clean enough for human consumption. Because treated wastewater usually contains less dissolved salts and metals and less organic material than natural saltwater, it causes less fouling and scaling in the membrane systems.

However, attempts to recycle wastewater for municipal use have often been met with resistance. "Using membranes to treat wastewater is going to be less expensive normally, but people just don't like the way it sounds," says Price. "Sometimes even I hesitate when people offer me a drink of it."

Paul Gagliardo, manager of strategic planning and applied research for the San Diego Water Department in California, found out recently how hard it can be to convince voters and legislators that recycling wastewater can be safe. A proposal to use reclaimed water to recharge a reservoir in that water-scarce city was recently defeated by the city council. "By 1995, we had analyses showing that we could safely and reliably make drinking water from sewage water by applying these [desalination] membranes," says Gagliardo. "But politics . . . and misinformation pretty much killed it." Ironically, Gagliardo points out, Las Vegas, Nevada, discharges water upstream of an aqueduct that routes Colorado River water to San Diego. "So we are already drinking treated wastewater," he says.

In San Diego and many other communities, the idea of processing seawater for drinking water does not draw nearly as much criticism, a fact that many scientists and conservationists see as a problem. "Conservation is the most cost-effective solution [to water scarcity]," says Price. "The second is water reuse and recycling. You really shouldn't go to desalination technologies as they currently exist for things like seawater except maybe as a third option, because it's so expensive."

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Suggested Reading

Buros OK. ABC's of desalting. Riyadh, Saudi Arabia:Saline Water Conversion Corporation, 1990.

Leitner and Associates. Potable water desalination in the U.S.: capital costs, operating costs and water selling prices. St. Leonard, MD:National Water Supply Improvement Association, 1992.

Leitner and Associates. Survey of U.S. costs and water rates for desalination and membrane softening plants. WTTP Report 24. Denver, CO:U.S. Department of the Interior, Bureau of Reclamation, 1997.

Smith BE. Desalting and ground water management in the San Joaquin Valley, California. Desalination 87:151–174, 1992.