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Facing the Freshwater Crisis

As demand for freshwater soars, planetary supplies are becoming unpredictable. Existing technologies could avert a global water crisis, but they must be implemented soon

By Peter Rogers

A friend of mine lives in a middle-class neighborhood of New Delhi, one of the richest cities in India. Although the area gets a fair amount of rain every year, he wakes in the morning to the blare of a megaphone announcing that freshwater will be available only for the next hour. He rushes to fill the bathtub and other receptacles to last the day. New Delhi's endemic shortfalls occur largely because water managers decided some years back to divert large amounts from upstream rivers and reservoirs to irrigate crops.

My son, who lives in arid Phoenix, arises to the low, schussing sounds of sprinklers watering verdant suburban lawns and golf courses. Although Phoenix sits amid the Sonoran Desert, he enjoys a virtually unlimited water supply. Politicians there have allowed irrigation water to be shifted away from farming operations to cities and suburbs, while permitting recycled wastewater to be employed for landscaping and other nonpotable applications.

As in New Delhi and Phoenix, policymakers worldwide wield great power over how water resources are managed. Wise use of such power will become increasingly important as the years go by because the world's demand for freshwater is currently overtaking its ready supply in many places, and this situation shows no sign of abating. That the problem is well-known makes it no less disturbing: today one out of six people, more than a billion, suffer inadequate access to safe freshwater. By 2025, according to data released by the United Nations, the freshwater resources of more than half the countries across the globe will undergo either stress—for example, when people increasingly demand more water than is available or safe for use—or outright shortages. By midcentury as much as three quarters of the earth's population could face scarcities of freshwater.

Scientists expect water scarcity to become more common in large part because the world's population is rising and many people are getting richer (thus expanding demand) and because global climate change is exacerbating aridity and reducing supply in many regions. What is more, many water sources are threatened by faulty waste disposal, releases of industrial pollutants, fertilizer runoff and coastal influxes of saltwater into aquifers as groundwater is depleted. Because lack of access to water can lead to starvation, disease, political instability and even armed conflict, failure to take action can have broad and grave consequences.

Fortunately, to a great extent, the technologies and policy tools required to conserve existing freshwater and to secure more of it are known; I will discuss several that seem particularly effective. What is needed now is action. Governments and authorities at every level have to formulate and execute concrete plans for implementing the political, economic and technological measures that can ensure water security now and in the coming decades.

Sources of Shortages

Solving the world's water problems requires, as a start, an understanding of how much freshwater each person requires, along with knowledge of the factors that impede supply and increase demand in different parts of the world. Malin Falkenmark of the Stockholm International Water Institute and other experts estimate that, on average, each person on the earth needs a minimum of 1,000 cubic meters (m^3) of water per year—equivalent to two fifths of the volume of an

Olympic-size swimming pool—for drinking, hygiene and growing food for sustenance. Whether people get enough depends greatly on where they live, because the distribution of global water resources varies widely.

Providing adequate water is especially challenging in drier, underdeveloped and developing nations with large populations, because demand in those areas is high and supply is low. Rivers such as the Nile, the Jordan, the Yangtze and the Ganges are not only overtaxed, they also now regularly peter out for long periods during the year. And the levels of the underground aquifers below New Delhi, Beijing and many other burgeoning urban areas are falling.

Shortages of freshwater are meanwhile growing more common in developed countries as well. Severe droughts in the U.S., for instance, have recently left many cities and towns in the northern part of Georgia and large swaths of the Southwest scrambling for water. Emblematic of the problem are the man-made lakes Mead and Powell, both of which are fed by the overstressed Colorado River. Every year the lakes record their ongoing decline with successive, chalky high-water marks left on their tall canyon walls like so many bathtub rings.

Golden Rule

Location, of course, does not wholly determine the availability of water in a given place: the ability to pay plays a major role. People in the American West have an old saying: “Water usually runs downhill, but it always runs uphill to money.” In other words, when supplies are deficient, the powers that be typically divert them to higher-revenue-generating activities at the expense of lower-revenue-generating ones. So those with the money get water, while others do not.

Such arrangements often leave poor people and nonhuman consumers of water—the flora and fauna of the adjacent ecosystems—with insufficient allocations. And even the best intentions can be distorted by the economic realities described by that Western aphorism.

A case in point occurred in one of the best-managed watersheds (or catchments) in the world, the Murray-Darling River Basin in southeast Australia. Decades ago the agriculturalists and the government there divided up the waters among the human users—grape growers, wheat farmers and sheep ranchers—in a sophisticated way based on equity and economics. The regional water-planning agreement allowed the participants to trade water and market water rights. It even reserved a significant part of the aqueous resource for the associated ecosystems and their natural inhabitants, key “users” that are often ignored even though their health in large measure underlies the well-being of their entire region. Water and marsh plants, both macro and micro, for example, often do much to remove human-derived waste from the water that passes through the ecosystems in which they live.

It turns out, however, that the quantities of water that the planners had set aside to sustain the local environment were inadequate—an underestimation that became apparent during periodic droughts—in particular, the one that has wrought havoc in the area for the last half a dozen years. The territory surrounding the Murray-Darling Basin area dried out and then burned away in tremendous wildfires in recent years.

The economic actors had all taken their share reasonably enough; they just did not consider the needs of the natural environment, which suffered greatly when its inadequate supply was reduced to critical levels by drought. The members of the Murray-Darling Basin Commission are now frantically trying to extricate themselves from the disastrous results of their misallocation of the total water resource.

Given the difficulties of sensibly apportioning the water supply within a single nation, imagine the complexities of doing so for international river basins such as that of the Jordan River, which borders on Lebanon, Syria, Israel, the Palestinian areas and Jordan, all of which have claims to the shared, but limited, supply in an extremely parched region. The struggle for freshwater has contributed to civil and military disputes in the area. Only continuing negotiations and compromise have kept this tense situation under control.

Determining Demand

Like supply, demand for water varies from place to place. Not only does demand rise with population size and growth rate, it also tends to go up with income level: richer groups generally consume more water, especially in urban and industrial areas. The affluent also insist on services such as wastewater treatment and intensive farm irrigation. In many cities, and in particular in the more densely populated territories of Asia and Africa, water demands are growing rapidly.

In addition to income levels, water prices help to set the extent of demand. For example, in the late 1990s, when my colleagues and I simulated global water use from 2000 until 2050, we found that worldwide water requirements would rise from 3,350 cubic kilometers (km^3)—roughly equal to the volume of Lake Huron—to 4,900 km^3 if income and prices remained as they were in 1998. (A cubic kilometer of water is equivalent to the volume of 400,000 Olympic swimming pools.) But the demand would grow almost threefold (to 9,250 km^3) if the incomes of the poorest nations were to continue to climb to levels equivalent to those of middle-income countries today and if the governments of those nations were to pursue no special policies to restrict water use. This increased requirement would greatly intensify the pressure on water supplies, a result that agrees fairly well with forecasts made by the International Water Management Institute (IWMI) when it considered a “business-as-usual,” or “do-nothing-different,” scenario in the 2007 study *Water for Food, Water for Life*.

Ways to Limit Waste

Given the importance of economics and income in water matters, it is clear that reasonable pricing policies that promote greater conservation by domestic and industrial users are worth adopting. In the past the cost of freshwater in the U.S. and other economic powers has been too low to encourage users to save water: as often happens when people exploit a natural resource, few worry about waste if a commodity is so cheap that it seems almost free.

Setting higher prices for water where possible is therefore near the top of my prescription list. It makes a lot of sense in developed nations, particularly in large cities and industrial areas, and more and more in developing ones as well. Higher water prices can, for instance, spur the adoption of measures such as the systematic reuse of used water (so-called gray water) for nonpotable applications. It can also encourage water agencies to build recycling and reclamation systems.

Raising prices can in addition convince municipalities and others to reduce water losses by improving maintenance of water-delivery systems. One of the major consequences of pricing water too low is that insufficient funds are generated for future development and preventive upkeep. In 2002 the U.S. Government Accountability Office reported that many domestic water utilities defer infrastructure maintenance so that they can remain within their limited operating budgets. Rather than avoiding major failures by detecting leaks early on, they usually wait until water mains break before fixing them.

The cost of repairing and modernizing the water infrastructures of the U.S. and Canada to reduce losses and ensure continued operation will be high, however. The consulting firm Booz Allen Hamilton has projected that the two countries will need to spend $3.6 trillion combined on their water systems over the next 25 years.

When the goal is to save water, another key strategy should be to focus on the largest consumers. That approach places irrigated agriculture in the bull’s-eye: compared with any other single activity, conserving irrigation flows would conserve dramatically more freshwater. To meet world food requirements in 2050 without any technological improvements to irrigated agriculture methods, farmers will need a substantial rise in irrigation water supplies (an increase from the current 2,700 to 4,000 km^3), according to the IWMI study.

On the other hand, even a modest 10 percent rise in irrigation efficiency would free up more water than is evaporated off by all other users. This goal could be achieved by stopping up leaks in the water-delivery infrastructure and by implementing low-loss storage of water as well as more efficient application of water to farm crops.
An agreement between municipal water suppliers in southern California and nearby irrigators in the Imperial Irrigation District illustrates one creative conservation effort. The municipal group is paying to line leaky irrigation canals with waterproof materials, and the water that is saved will go to municipal needs.

An additional approach to saving irrigation water involves channeling water that is eventually intended for crop fields to underground storage in the nongrowing season. In most parts of the world, rainfall and snow accumulation—and runoff to rivers—peak during the nongrowing seasons of the year, when demand for irrigation water is lowest. The fundamental task for managers is therefore to transfer water from the high-supply season to the high-demand season when farmers need to irrigate crops.

The most common solution is to hold surface water behind dams until the growing season, but the exposure evaporates much of this supply. Underground storage would limit evaporation loss. For such storage to be feasible, engineers would first have to find large subsurface reservoirs that can be recharged readily by surface supplies and that can easily return their contents aboveground when needed for irrigation. Such “water banks” are currently operating in Arizona, California and elsewhere.

More extensive use of drip-irrigation systems, which minimize consumption by allowing water to seep in slowly either from the soil surface or directly into the root zone, would also do much to stem demand for irrigation water. Investments in new crop varieties that can tolerate low water levels and drought, as well as brackish and even saline water, could also help reduce requirements for irrigation water.

Given the rising demand for agricultural products as populations and incomes grow, it is unlikely that water managers can significantly lower the quantity of water now dedicated to irrigated agriculture. But improvements in irrigation efficiency as well as crop yields can help hold any increases to reasonable levels.

More Steps to Take
Keeping the demand for irrigation water in arid and semiarid areas down while still meeting the world's future food requirements can be supported by supplying "virtual water" to those places. The term relates to the amount of water expended in producing food or commercial goods. If such products are exported to a dry region, then that area will not have to use its own water to create them. Hence, the items represent a transfer of water to the recipient locale and supply them with so-called virtual water.

The notion of virtual water may sound initially like a mere accounting device, but provision of goods—and the virtual-water content of those goods—is helping many dry countries avoid using their own water supplies for growing crops, thus freeing up large quantities for other applications. The virtual-water concept and expanded trade have also led to the resolution of many international disputes caused by water scarcity. Imports of virtual water in products by Jordan have reduced the chance of water-based conflict with its neighbor Israel, for example.

The magnitude of annual global trade in virtual water exceeds 800 billion m^3 of water a year; the equivalent of 10 Nile Rivers. Liberalizing trade of farm products and reducing tariff restrictions that now deter the flow of foodstuffs would significantly enhance global virtual-water flows. Truly free farm trade, for instance, would double the current annual total delivery of virtual water to more than 1.7 trillion m^3.

Whatever benefits the world may accrue from virtual-water transfers, the populations of growing cities need real, flowing water to drink, as well as for hygiene and sanitation. The ever expanding demand for urban, water-based sanitation services can be reduced by adopting dry, or low-water-use, devices such as dry composting toilets with urine separation systems. These technologies divert urine for reuse in agriculture and convert the remaining waste on-site into an organic compost that can enrich soil. Operating basically like garden compost heaps, these units employ aerobic microbes to break down human waste into a nontoxic, nutrient-rich substance. Farmers can exploit the resulting composted organic matter as crop fertilizer. These techniques can be used safely, even in fairly dense urban settings, as exemplified by installations at the Gebers Housing Project in a suburb of Stockholm and many other pilot projects.

Essentially, civil engineers can employ this technology to decouple water supplies from sanitation systems, a move that could save significant amounts of freshwater if it were more widely employed. Moreover, recycled waste could cut the use of fertilizer derived from fossil fuels.

Beyond constraining demand for freshwater, the opposite approach, increasing its supply, will be a critical component of the solution to water shortages. Some 3 percent of all the water on the earth is fresh; all the rest is salty. But desalination tools are poised to exploit that huge source of salty water. A recent, substantial reduction in the costs for the most energy-efficient desalination technology—membrane reverse-osmosis systems—means that many coastal cities can now secure new sources of potable water.

During reverse osmosis, salty water flows into the first of two chambers that are separated by a semipermeable (water-passing) membrane. The second chamber contains freshwater. Then a substantial amount of pressure is applied to the chamber with the salt solution in it. Over time the pressure forces the water molecules through the membrane to the freshwater side.

Engineers have achieved cost savings by implementing a variety of upgrades, including better membranes that require less pressure, and therefore energy, to filter water and system modularization, which makes construction easier. Large-scale desalination plants using the new, more economical technology have been built in Singapore and Tampa Bay, Fla.

Scientists are now working on reverse-osmosis filters composed of carbon nanotubes that offer better separation efficiencies and the potential of lowering desalination costs by an additional 30 percent. This technology, which has been demonstrated in prototypes, is steadily approaching commercial use. Despite the improvements in energy efficiency, however, the applicability of reverse osmosis is to some degree limited by the fact that the technology is still energy-intensive, so the availability of affordable power is important to significantly expanding its application.

A Return on Investment

Not surprisingly, staving off future water shortages means spending money—a lot of it. Analysts at Booz Allen Hamilton have estimated that to provide water needed for all uses through 2030, the world will need to invest as much as $1 trillion a year on applying existing technologies for conserving water, maintaining and replacing infrastructure, and constructing sanitation systems. This is a daunting figure to be sure, but perhaps not so huge when put in perspective. The required sum turns out to be about 1.5 percent of today's annual global gross domestic product, or about $120 per capita, a seemingly achievable expenditure.

Unfortunately, investment in water facilities as a percentage of gross domestic product has dropped by half in most countries since the late 1990s. If a crisis arises in the coming decades, it will not be for lack of know-how; it will come from a lack of foresight and from an unwillingness to spend the needed money.

There is, however, at least one cause for optimism: the most populous countries with the largest water infrastructure needs—India and China—are precisely those that are experiencing rapid economic growth. The part of the globe that is most likely to continue suffering from inadequate water access—Africa and its one billion inhabitants—spends the least on water infrastructure and cannot afford to spend much; it is crucial, therefore, that wealthier nations provide more funds to assist the effort.

The international community can reduce the chances of a global water crisis if it puts its collective mind to the challenge. We do not have to invent new technologies; we must simply accelerate the adoption of existing techniques to conserve and enhance the water supply. Solving the water problem will not be easy, but we can succeed if we start right away and stick to it. Otherwise, much of the world will go thirsty.