



Water World 2000

At the dawning of a new millennium, at least one-fifth of all people worldwide lack access to safe drinking water, according to a 1999 United Nations (UN) comprehensive assessment of world water resources, and more than one-half of all people lack access to adequate sanitation. These problems will almost certainly get much worse as the earth's population grows from today's 6 billion to an expected 7.3–8.3 billion people by 2025, according to the UN Population Division.

During the last century in particular, steps have been taken to develop the technology and social policy to address questions of access to potable water, adequate sanitation, and means of improving water quality. Improvements have been made, mainly in developed countries. However, problems continue even there, and the situation in developing countries is far worse.

In developed countries, including the United States, western European nations, and Japan, some drinking water supplies contain synthetic organic chemicals, lead, arsenic, and fecal wastes that carry dangerous bacteria, viruses, and parasites, potentially posing increased risks of cancer, infections, and birth defects. Polluted water can cause a variety of gastrointestinal illnesses, including dehydration from severe diarrhea or vomiting that can be fatal in children, the elderly, and people with weakened immune systems. Industries discharge wastes into rivers and streams or dispose of them in landfills, lagoons, and dumps, where the pollution can leak into shallow water tables connected to lakes and streams, and eventually into aquifers. In the United States, for example, fertilizers and pesticides spread on farms and lawns filter through the ground into the water table or wash into streams and lakes, which supply half of the nation's drinking water.

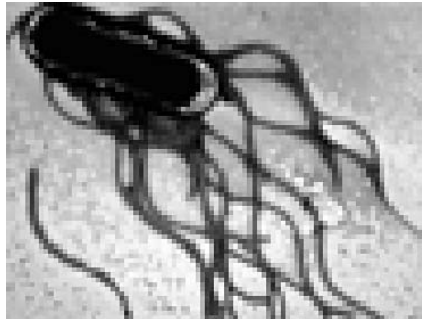
Most cities in developing countries discharge 80–90% of their untreated sewage directly into rivers and streams, which are used for drinking, bathing, and washing, according to Sandra Postel, director of the Global Water Policy Project, a research program on sustainable water use. For example, of India's 3,119 larger cities, only 209 have partial wastewater treatment plants. Just 8 have full treatment facilities.

In recent years, this lack of sewage treatment has allowed dangerous microorganisms to spread, as in South America, where the cholera bacterium threatens drinking water and food supplies. Today, impoverished people in developing countries still face catastrophic losses of life due to dirty water. Human feces remains one of the world's most dangerous pollutants, spreading microbes that cause typhoid, cholera, diarrheal illnesses, amoebic dysentery, and other virulent diseases. Diseases caused by tainted drinking water and food claim nearly two million lives a year among children under the age of five worldwide, according to a 1999 report by the World Health Organization (WHO) titled *Removing Obstacles to Healthy Development*.

Starting in Soho

In 1854, the Soho neighborhood of London was rocked by a cholera epidemic. Physician John Snow, who suspected that contaminated water was causing the outbreak, drew a map indicating the location of every cholera case in Soho. From this map, Snow could see that the highest concentration of illness occurred in homes that used the public water pump on Broad Street. After he recommended that authorities remove the pump, the number of new cholera cases in Soho plummeted. Snow's brainstorm was just one part of a revolution in public health in the 1840s and 1850s, when London, Paris, and other European cities began to battle waterborne infectious diseases by improving sewer systems. Largely as a result of this revolution, life expectancy rose dramatically over the next half-century.

After the turn of the 20th century, improvements in water supplies picked up momentum throughout the industrializing world. In 1908, Jersey City, New Jersey, became the first municipality in the United States to treat drinking water with chlorine to reduce health risks from dangerous microorganisms. Nevertheless, in the 1920s and 1930s there were a number of outbreaks of typhoid fever and amoebic dysentery in the United States after people drank contaminated water. By 1945, to prevent such outbreaks, large water systems were using disinfectants (especially chlorine) and improved filtration, while communities provided better disposal of wastewater.



Partnership for Food Safety Education

Micromenace. In developed and developing countries alike, microbial contaminants such as *Salmonella* plague drinking water supplies.

Even today, though, sewage treatment is not aimed at controlling specific microbial contaminants, and microbial pollution has again emerged as a serious problem in the United States and other developed countries. Microbial pathogens in U.S. public water supplies sicken hundreds of thousands of people each year, and though most of these illnesses are mild, disappearing after a few days, chronic outcomes such as myocarditis resulting from these infections are of significant concern. Only in some states do drinking water suppliers monitor and treat for certain dangerous viruses and parasites.

Meanwhile, thousands of public water systems annually violate one or more federal drinking water regulations. In the great majority of cases, small systems, which serve fewer than 3,300 people, are the chronic violators. One problem is that small systems must comply with standards for treatment and monitoring that were developed as affordable for large systems. Because small systems do not have economies of scale to cope with the growing costs of new rules, even the most efficient small suppliers struggle to keep up.

But in larger water systems, major accidents still happen. In late March and early April of 1993, a surge of the parasite *Cryptosporidium* slipped through the water treatment filters in Milwaukee, Wisconsin. An estimated 400,000 people became sick from drinking the contaminated water, suffering from diarrhea, abdominal cramping, nausea, vomiting, and fever. At least 50 people with compromised immune systems died in the wake of the outbreak. *Cryptosporidium* is an especially difficult organism to control because traditional disinfectants such as chlorine don't kill it, and the organism must be filtered out.

Fifteen years ago, the U.S. Environmental Protection Agency (EPA) and Congress primarily focused their attention on toxic chemicals in drinking water. In 1986, when the Safe Drinking Water Act was first reauthorized, Congress sought to

limit certain chemicals in drinking water to address a possible cancer risk. Congress instructed the EPA to establish standards for 83 contaminants within three years and for 25 new chemical contaminants every three years after that.

In 1996, when the Safe Drinking Water Act was again reauthorized, the requirement for new chemical standards was drastically scaled back, and Congress and the EPA set a new health priority for *Cryptosporidium* and other dangerous waterborne microbes. Nevertheless, health officials were still concerned about by-products of chlorine and other disinfectants that may cause some forms of cancer. In 1996, the EPA promulgated an Information Collection Rule requiring water systems that serve more than 100,000 people to collect and report information on the presence and concentrations of microbial contaminants and disinfection by-products.

In December 1998, the EPA proposed the Interim Enhanced Surface Water Treatment Rule, which would require improvements in filtration at water systems that serve at least 10,000 people. In addition, states would be required to conduct sanitary surveys of all water systems, including those that serve fewer than 10,000 people.

Experts say the United States probably has some of the cleanest drinking water in the world. The vast majority of industrial discharges into waterways are regulated and treated to some degree. After massive public investments under the Clean Water Act over the past two decades, cities and towns have upgraded their treatment of sewage. And drinking water suppliers monitor and treat for chemical contaminants and microorganisms to protect public health.

A Developing Problem

Developing countries have not been as successful in implementing such monitoring and treatment programs. Joan B. Rose, a microbiologist at the University of South Florida in St. Petersburg who has organized workshops in Brazil, Mexico, Argentina, and Panama on water monitoring and risk assessment, notes that South American nations generally don't have sewage treatment. These nations have far greater problems with drinking water contamination than does the United States.

In the early 1990s, an epidemic of cholera sickened 350,000 people throughout the continent, killing more than 3,600. Cholera was able to spread rapidly through South America once it took hold in the early 1990s largely because the bacterium moved from wastewater systems to drinking water supplies, Rose says.

Today, 17 cities in the developing world are considered megacities, with more than 10

million people. This explosive growth of densely populated cities with unsafe water, poor sanitation, and widespread poverty has established an ideal breeding ground for infectious diseases, according to the WHO. It is difficult and expensive to supply clean water and adequate sanitation to 10–20 million people living in a concentrated area, as it requires enormous investments in sewer construction, treatment plants, and personnel.

Even so, large cities in developing countries receive the overwhelming majority of public funds spent on improved water supplies and sanitation. “Governments and businesses in developing countries are located in the urban areas,” says Ted Kuepper, project manager for Global Water, an international nonprofit organization that has helped establish deep wells for drinking water in countries such as Kenya, Laos, and Peru. “The political power is in the cities, and leaders don’t expect to get anything back politically from rural areas, which have been incredibly neglected over the years [in terms of investments in clean water],” he says.

In many poor villages, people have to rely on the water that’s easiest to reach through shallow groundwater wells, usually less than 10 feet deep, or mud holes used by both animals and humans. Even when there is a stream or river nearby, these water sources are frequently polluted with animal and human waste.

Especially for mothers in poor communities, the convenience and quantity of water are crucial, according to Sandy Cairncross, head of the Disease Control & Vector Biology Unit at the London School of Hygiene & Tropical Medicine. Women with small children particularly need a nearby source of water to maintain domestic hygiene, because numerous infectious diseases are spread primarily by contact with human waste. Microorganisms that cause cholera, severe diarrhea, and other illnesses are often present in huge numbers in infected human feces, and if someone drinks water containing these dangerous microbes, the illness can be quickly passed on. Diarrheal infections travel not only through water supplies but also via contaminated food, utensils, and fingers. Cairncross notes that in Bangladesh, poor women sometimes use a section of their saris to wipe dishes, clean children’s faces, and wipe children’s bottoms. Thus, a local water supply can be relatively clean, yet diseases still spread. And they still kill.

Parents are often shocked at how quickly severe dehydration can kill young children. Yet diarrheal afflictions can be readily treated with an oral rehydration solution. Indeed, over the past decade Mexico has significantly reduced death rates from waterborne infectious diseases by distributing this

medicine to health centers and improving health education, according to the WHO report.

Still, it’s very difficult to control diarrheal diseases without readily available water to maintain hygiene. For many poor people, the only source of water is a long hike from home. “If the water supply is a mile away, women and children are spending a good part of their day just walking back and forth getting it,” says Kuepper.

But when people have taps near their homes, their water use rises dramatically, and “most of the increase in water consumption is for hygiene purposes,” says Cairncross. Studies show, he says, that hygiene does improve when people have on-plot or in-house water supplies. But this can be economically impractical. “Piped-in water for every home is very expensive,” says Postel. The challenge for many poor regions is to find methods of supplying low-cost, convenient, clean water to neighborhoods and communities, without necessarily providing piped-in supplies to individual homes.

A Scarce Resource

In the coming decades, there will be increasing competition for water supplies worldwide. North Africa and the Middle East are the global regions most challenged by water scarcity today. But sub-Saharan Africa, including countries such as Rwanda and Kenya, will also be affected as the region’s population doubles or even triples in size over the next 50 years, predict Robert Engelman and Tom Gardner-Outlaw, coauthors of the 1997 report *Sustaining Water, Easing Scarcity: A Second Update*, published by Population Action International, a nonprofit organization based in Washington, DC. The researchers examined how

much renewable fresh water is now available in each country, and by using various UN projections on population growth, estimated how much water will be available in the future. According to the report, by the year 2050 at least one in four of the world’s people is projected to live in a country with a

chronic shortage of fresh water. Still, the report refers to water scarcity in terms of economic development and agricultural needs—not in terms of drinking water.

In general, few countries maintain significant data on drinking water as a particular category, with the exception of the United States and certain other developed nations. “For most developing countries, drinking water is not a special category,” says Engelman, who is also director of the Population and Environment Program at Population Action International. “Drinking water is a very small minority of water use.”

Even so, experts agree that rapidly growing cities, with rising populations and water-hungry industries, will increasingly compete for supplies now used by agriculture. Today, irrigation consumes about 70% of available fresh water worldwide. But there is only so much water to go around in water-scarce regions,



A precious commodity. The need for clean water for hygiene is particularly pressing for women and children in poor communities, who may be most susceptible to the transmission of infectious diseases.

says Postel. In several international river basins, rivers are shared by a number of countries, and populations in those countries are increasing at a fairly significant rate. That’s causing all kinds of demands for water—for irrigation to grow food, for developing industry for jobs, and for household use. In the Nile Basin, for example,

Ethiopia, Sudan, and Egypt are competing for irrigation water, and this competition is expected to grow more heated as the number of people there increases rapidly over the next 30 years. Still, providing drinking water is a priority for most governments, and where water is scarce governments are shifting supplies from agriculture to industry and to cities for household use. This phenomenon is occurring in parts of India, China, Southeast Asia, and even the United States.

Some of the world's most serious water shortages are caused by government policies that encourage waste. In many developing countries, water is heavily subsidized, priced far lower than the cost of storing, transporting, and treating it, and with such low prices, there is little incentive to conserve water. Water subsidies are provided primarily to prosperous city dwellers with access to public systems and to rural farmers who can take irrigation water essentially for free.

In the vast shantytowns surrounding the megacities of the developing world, municipal services, including water and sewage, are not available. So the poor have to rely on vendors, who show up in neighborhoods about twice a week with water that may have been taken from highly polluted sources. Yet poor citizens end up paying a large portion of their income for this water. Slum dwellers pay about 12 times more per unit for this "street water" than the prices that middle-class residents pay for piped-in municipal supplies, according to a 16-city review of water vending presented in August 1999 at the Second Meeting of the World Commission on Water for the 21st Century, which is supported by agencies of the UN and the World Bank. The review reported the example of Lima, Peru, where a poor family typically pays street vendors \$3 per cubic meter of water, more than 20 times what a middle-class family pays for water through a piped-in house connection.

Some of the largest cities, such as Mexico City, depend on diminishing supplies of groundwater, which is often the cleanest source of water. Underground aquifers begin 30–100 feet beneath the land surface. Because water gravitates very slowly from the earth's surface to an aquifer—a fraction of an inch to a few feet per day—it usually takes many years for an aquifer to be refilled. When enormous amounts of water are drawn out too quickly with powerful pumps, aquifers can be depleted. As water quantity shrinks, water quality can be affected, because declining supplies lose their capacity to dilute pollutants and salinity. For example, in Bangladesh and West Bengal, India, receding water tables have exposed arsenic-laden sediments to oxygen, apparently converting them to a water-soluble form.

Tens of millions of people in West Bengal are drinking groundwater with arsenic concentrations well above acceptable levels. Thousands have been diagnosed with symptoms of arsenic poisoning such as skin lesions, according to the April 1999 *Source Bulletin*, published by the International Water and Sanitation Centre and the Water Supply and Sanitation Collaborative Council, agencies of the WHO.

Climate Change

Yet another factor affecting the availability of clean water is climate change, which has been credited as the cause of outbreaks of waterborne illnesses around the world. Global warming is intensifying the hydrological cycle, drawing more moisture into the atmosphere and altering patterns of precipitation. "A moisture-laden atmosphere . . . generates more tropical-like downpours that . . . flush nutrients, chemicals, and microorganisms into waterways," wrote Paul R. Epstein, associate director of the Center for Health and the Global Environment at Harvard Medical School in Boston, Massachusetts, in a 16 July 1999 article in *Science*. Massive flooding often contaminates wells and water treatment facilities, allowing the spread of the cholera bacterium and other pathogens.

For instance, during the 1997–1998 El Niño event, the Horn of Africa was struck by heavy rains—up to 40 times the average rainfall—causing tens of thousands of cases of cholera. Hurricane Mitch, which was strengthened by the warm waters of the Caribbean, battered Central America in November 1998, spawning more than 30,000 cases of cholera. And many microorganisms are thriving in the new climate conditions. "With warming, we're seeing more growth of organisms [that cause disease]," says Epstein. "Warm temperatures can increase the rate of growth of microorganisms such as *Salmonella*." Indeed, a recent study by researchers at the University of South Florida and The Johns Hopkins University in Baltimore, Maryland, has shown that in the last 20 years 20–40% of drinking water–related outbreaks in the United States have occurred during extreme precipitation events. The researchers mapped the outbreaks from 1970 to 1994 and then compared precipitation data during the outbreaks to average rainfall for that time of year. Says Rose, "The results have suggested that rainfall is a significant contributor to the contamination that overwhelms many water systems."

Meanwhile, some dry regions are experiencing more severe droughts as their climates change. In drought conditions, people lack enough water to stay clean, and disease can spread rapidly. Moreover, in some arid

regions, a lack of water has been creating environmental refugees in recent years. Driven from their homes to look for food and water, these refugees eventually settle in overcrowded temporary villages, where they are vulnerable to epidemics of dysentery. "The main reason that people have to move from their homes is because of a lack of water," says Kuepper.

Where the Water Is

In most regions of the world, water is not so much scarce as it is badly distributed, says Postel. "There is enough to provide everyone with drinking water, but governments, international agencies, and the private sector have not been mobilized to provide that water."

Kuepper agrees that impoverished rural areas could gain access to water at minimal cost. In many places, he says, "there are stable and consistent groundwater supplies, where aquifers are just so large. These are places that experience scarcity, yet local people lack the technologies to gain access to groundwater." Global Water projects help nongovernmental agencies in developing countries build low-cost, small wells less than 100 feet deep that can pump 10–15 gallons a minute with hand pumps. When entire villages are supplied with these wells, solar-powered water pumps are provided as well. Getting funding for such projects, however, is always a struggle, Kuepper says.

The UN Environment Programme (UNEP) is proposing major international investments in water and sewage distribution systems. The agency notes that water could be provided in rural areas through low-cost technologies similar to those provided by Global Water, including hand pumps and rainwater collection. These tools would help bring water to entire rural villages. In cities, UNEP recommends building better water systems with more pipes, pumps, worker training, and development and strengthening of management policies. In total, low-cost safe water could be brought to people who need it for \$23–25 billion per year over 8–10 years, according to UNEP.

Now international agencies want to bring many of the basic health advances established in industrialized nations over the past 150 years to the rest of the world. "The health benefits provided by better water and sanitation are huge," notes John Briscoe, senior water advisor at the World Bank. "When services were improved in industrial countries in the 19th and 20th centuries, the impact on health was revolutionary." Experts suggest that such a revolution is just what the 21st century needs as well.

John Tibbetts



Hans Paerl

The Other Side of the Coin: Too Much Water

The 1999 hurricane season was a brutal one for eastern North Carolina, an area of 18,000 square miles and 2.1 million people. The region was deluged by three giant storms and more than three feet of rain in less than two months. First, Hurricane Dennis battered North Carolina for six days in late August and early September, dumping 8 inches of rain. Just two weeks later, on September 16, Hurricane Floyd poured up to 20 inches onto the eastern part of the state. Finally, on October 18, Hurricane Irene brought a third round of torrential rains, dumping up to 11 inches on some parts of North Carolina.

The environmental damage from the storms was widespread. Throughout eastern North Carolina, the unusually high amount of rain dropped by the storms caused massive flooding, knocking out electricity in at least 24 municipal sewage treatment plants and causing spills of raw sewage into coastal rivers, especially affecting the Tar, Neuse, and Cape Fear. According to Susan Massengale, spokesperson for the North Carolina Division of Water Quality, the storm caused five farm-waste lagoons to breach and hundreds of waste lagoons were filled to high levels with rainwater so that farmers had to pump huge volumes of diluted animal waste onto already-saturated sprayfields to keep lagoon dams from breaking or overtopping. "It could be that the largest source of contaminants was from pumping to maintain safety of the lagoons," says Joe Rudek, a senior scientist with the Environmental Defense Fund.

The stormwater from the three hurricanes mixed with raw sewage, junkyard waste, propane tanks, underground gasoline tanks, runaway oil drums, and sediments from farm fields. Stormwater included "anything you could imagine that could be uprooted or inundated or released during the flooding event," pouring down rivers into Pamlico Sound, the nation's second-largest estuary, says Hans Paerl, a marine scientist at the University of North Carolina at Chapel Hill.

The floodwaters polluted wells, broke water mains, and threatened water supplies with bacteria, viruses, and parasites, which can cause a variety of diarrheal illnesses. After Floyd, National Guard trucks and helicopters were needed to deliver clean water to several counties in eastern North Carolina.

Yet in the first two weeks after Floyd, state surveyors found only a slight increase in reported gastrointestinal illnesses and no outbreaks, says Debbie Crane, a spokesperson for the North Carolina Department of Health and Human Services. Health officials who surveyed emergency rooms and some doctors' offices suspect that stress may have been the contributing factor for the increase in

reported cases, says Crane. By the third week after the storm, no further increase in reported cases was seen.

But surveys don't tell the whole story. "Most people don't go to the doctor when they get sick [with gastrointestinal ailments] after a flood," says Joan B. Rose, a microbiologist at the University of South Florida in St. Petersburg who studies pathways and concentrations of pathogenic microorganisms in stormwater runoff. "They're trying to clean up their house, contact their insurance company. In emergency rooms, you're more likely to see young children and infants taken in, not adults."

Meanwhile, the post-Floyd flooding was washing a huge pulse of freshwater into Pamlico Sound. Because freshwater is less dense than saltwater and floats on top, it created an "oil-and-vinegar effect," says Paerl. The freshwater on top also sealed off oxygen from the deeper brackish waters of the sound. As a result, two weeks after Floyd, Paerl found extremely low oxygen concentrations in the bottom waters of Pamlico Sound—1 milligram per liter compared with the normal 7 milligrams. The conditions in Pamlico Sound were reminiscent of conditions in the Gulf of Mexico after its "dead zone" doubled in 1993, due, some scientists believe, to fertilizer runoff after massive Midwestern floods that year.

Hurricane Irene, though, brought a surprising development. That storm stirred up the water column, recirculating fresh- and saltwater, "flipping the sound over," says Paerl. The combination of storms has caused a large-scale freshening of Pamlico Sound, decreasing its surface water salinity from about 20 parts per thousand to about 6 or 7 parts per thousand and changing the habitat of the sound for saltwater species.

But it could be next spring or summer, Paerl notes, before scientists can determine the longer-term effects of the 1999 hurricanes. Over the winter, scientists expect to see continuing freshwater flows from these storms and large loads of nutrients and organic matter pouring into the sound. When North Carolina waters heat up again during spring and summer, says Paerl, there is a greater likelihood of algal blooms. Nutrients and warm temperatures stimulate algal blooms, which subsequently decompose, potentially robbing the bottom water of oxygen.

Most of the nutrients, freshwater, and pollutants flowing into Pamlico Sound will likely remain there through the summer. The sound, blocked off by the Outer Banks, has only three very narrow outlets to the Atlantic Ocean. "It's a very large body of water that doesn't exchange very readily [with the Atlantic]," says Paerl. "A drop of water stays in that system for about a year." —**John Tibbets**