Arsenic in drinking water could severely poison 50 million people worldwide. Strategies being tested in Bangladesh might help prevent the problem

ARSENIC CRISIS in Bangladesh

By A. Mushtaque R. Chowdhury

Photography by Dilip Mehta

ARSENIC FLOWS from a tubewell in Bilkada village in Bangladesh. Farmer Abdul Rahman, whose foot was amputated after cancer caused by the contaminated water, looks on as a neighbor pumps.

A cold, clear, sparkling flow gushes from the tubewell where Pinjra Begum used to collect drinking water for her family. Married at age 15 to a millworker, she had made a pretty bride. Soon, however, her skin began to turn blotchy, then ultimately gangrenous and repulsive. Her husband remarried. In 2000 she died of cancer, at 26 years of age, leaving three children.

Pinjra Begum was poisoned by the beautiful water she had faithfully pumped. In the 1970s and 1980s the Bangladesh government, along with international aid agencies spearheaded by UNICEF, undertook an ambitious project to bring clean water to the nation's villages. Too many children were dying of diarrhea from drinking surface water contaminated with bacteria. The preferred solution was a tubewell: a simple, hardy, hand-operated pump that sucks water, through a pipe, from a shallow underground aquifer. The well-to-do could afford them, and with easy loans from nongovernmental agencies, many of the poor also installed the contraptions in their courtyards. A tubewell became a prized possession: it lessened the burden on women, who no longer had to trek long distances with their pots and pails; it reduced the dependence on better-off neighbors; and most important, it provided pathogen-free water to drink. By the early 1990s 95 percent of Bangladesh's population had access to "safe" water, virtually all of it through the country's more than 10 million tubewells—a rare success story in the otherwise impoverished nation.

Alas, somebody—everybody—neglected to check the water for arsenic. As early as 1983, dermatologist Kshitish C. Saha of the School of Tropical Medicine in neighboring Kolkata (Calcutta), India, had identified the skin lesions on some patients as arising from arsenic poisoning. He traced the mineral to water from tubewells. The patients were mostly from the eastern Indian state of West Bengal, which shares some aquifers with Bangladesh; more pointedly, some were immigrants from Bangladesh. Over the next few years, environmental scientist Dipankar Chakraborti of Jadavpur University in Kolkata established that many aquifers in West Bengal were severely contaminated with arsenic. Yet the British Geological Survey (BGS) conducted an extensive test of Bangladesh's water supply in 1993 and pronounced it safe, not having tested for arsenic. That same year Abdul W. Khan of the Department of Public Health Engineering in Bangladesh discovered the mineral in tubewell water in the western district of Nawabganj.

ABANDONED by her husband, Ambia Khatum, with her daughter, displays characteristic sores. Lesions on the palms and soles make daily chores painful.

DILIP MEHTA *Contact Press Images*

Today around 30 percent of Bangladesh's tubewells are known to yield more than 50 micrograms of arsenic per liter of water, with 5 to 10 percent providing more than six times this amount. The Bangladesh government specifies more than 50 micrograms per liter as being dangerous. (I use this standard in the article. The World Health Organization's upper limit, which is also the recently revised standard of the U.S. Environmental Protection Agency, is 10 micrograms. Unfortunately, this amount is too small to test for accurately in the field.) That means at least 35 million people—almost one quarter of the population—are drinking potentially fatal levels of arsenic.

Another concern is that Bangladeshis may be ingesting arsenic through a second route: the grain they eat two or three times a day. In the dry months, rice fields are irrigated with pumped underground water. Recently researchers from the University of Aberdeen in Scotland found that the arsenic content of local rice varies from 50 to 180 parts per billion, depending on the rice variety and on where it is grown. (Fifty parts per billion is the equivalent of 50 micrograms per liter in water.) A few vegetables, in particular an edible tuber containing an astonishing 100 parts per *million* of arsenic, are also contaminated. Hardly any guidelines exist as to what levels of arsenic in food might be dangerous.

And Bangladesh is not alone. The mineral occurs in the water supply of communities in diverse countries, such as India, Nepal, Vietnam, China, Argentina, Mexico, Chile, Taiwan, Mongolia and the U.S. [*see map on opposite page*]. As many as 50 million people worldwide could be severely affected eventually. Arsenic in drinking water thus constitutes the largest case of mass poisoning in history, dwarfing Chernobyl.

Mineral Water

THE FIRST SIGN of poisoning, which may appear as long as 10 years after someone starts drinking arsenic-laden water, is black spots on the upper chest, back and arms, known as melanosis. Palms of the hands or soles of the feet become hard and lose sensation (keratosis). The patient may also suffer from conjunctivitis, bronchitis and, at very high concentrations of arsenic, diarrhea and abdominal pain. These symptoms describe the first stage of arsenicosis, as arsenic-induced ailments are known. In the second stage, white spots appear mixed up with the black (leucomelanosis), legs swell, and the palms and soles crack and bleed (hyperkeratosis). These sores, which are highly characteristic of arsenic poisoning, are painful and can become infected; they make working and walking difficult. In addition, neural problems appear in the hands and legs, and the kidneys and liver start to malfunction. In the third stage the sores turn gangrenous, kidneys or liver may give way, and in around 20 years, cancers show up.

Pinjra Begum died unusually young; she may have been drinking high levels of arsenic since childhood. One study in Taiwan found that drinking 500 micrograms of arsenic per liter of water led to skin cancer in one out of 10 individuals. The major cause of death, however, is internal cancers, especially of the bladder, kidney, liver and lung. A 1998 study in northern Chile attributed 5 to 10 percent of all deaths in those older than 30 to arsenic-induced internal cancers. These people were exposed, at least initially, to around 500 micrograms per liter. The U.S. National Research Council concluded in 1999 that the combined cancer risk from ingesting more than 50 micrograms of arsenic per liter of water could easily lead to one in 100 people dying of cancer.

Drinking water with high levels of arsenic can also lead to neurological and cardiovascular complications. The extent of poisoning depends on the dose and duration of exposure, interactions of the arsenic with other dietary elements, and the age and sex of the individual. So far no one knows the true impact of the poison in Bangladesh. Anecdotal evidence suggests tens of thousands of cases of arsenicosis and reports a "large number" of deaths. Although a few cancer cases are seen, this epidemic has yet to peak.

Unfortunately, the Bangladesh health system is unprepared for a crisis of this magnitude. Health workers can offer ointments to relieve the pain of lesions and to prevent infection, and gangrenous limbs can be amputated, but chronic arsenic poisoning has no real remedy. One suggested treatment, chelation, requires the patient to ingest a chemical that binds to arsenic and aids its excretion. Yet chelation is of limited value, because even without it the body ejects arsenic quite efficiently; besides, the patient could go right back to ingesting contaminated water. Drinking safe water, on the other hand, seems to dispel the early symptoms of arsenicosis. But providing such water is not as easy as it sounds.

The source of—and perhaps the solution to—Bangladesh's arsenic problem lies under the ground. The nation is largely a delta, formed by silt deposited over 250 million years by two great Himalayan rivers, the Ganga and the Brahmaputra. In some areas, the sediment layer is as much as 20 kilometers deep. Most of the poisoned aquifers are shallow, however, from 10 to 70 meters deep, and lie to the south and southeast of the country. The BGS notes that around 18,000 years ago, when the sea level dropped by around 100 meters, the rivers cut deep channels into the existing sediment. In later years, these valleys filled up with a gray clay that seems to hold the poison. Older, brown alluvium, such as in the northwest or the hilly regions, is less contaminated.

An early hypothesis by Chakraborti holds that the arsenic is associated with iron pyrites and enters the aquifers by an oxidation process. So overuse of groundwater, mainly for irrigation, lowers the water tables, allowing air to reach the contaminated clay and release the arsenic. By this theory, human activity is aggravating the arsenic problem. Nowadays a rival hypothesis, that of reduction, has gained currency. According to the BGS, the arsenic is adsorbed onto particles of iron oxyhydroxide, which are reduced by organic extracts in the water itself, releasing arsenic. If so, the mineral has always been in the water. Controversy continues to rage, however: Chakraborti asserts that some tubewells he measured to be arsenic-free a decade ago are now poisoned, suggesting that complex geochemical processes are even now under way.

In response to the crisis, the government created the Bangladesh Arsenic Mitigation and Water Supply Project in 1998, to which effort the World Bank provided a loan of $32.5 million. Much of this money still lies unused because of fundamental uncertainties in how to proceed. The Bangladesh Rural Advancement Committee (BRAC), a nongovernmental organization of which I am a deputy executive director, has, however, been working since 1997 to find an answer to the arsenic dilemma.

Face Forward

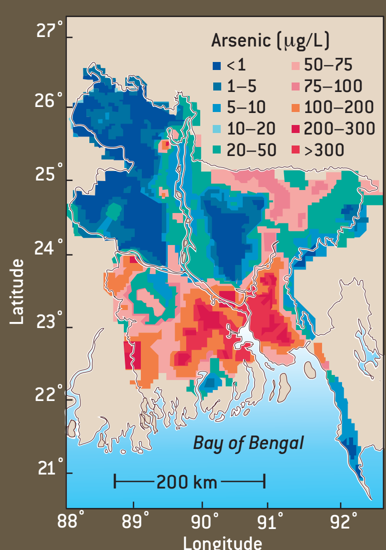
INITIALLY VILLAGERS in the two regions where we researched solutions to the arsenic problem—Sonargaon to the east and Jhikargacha to the west—would

THE DISTRIBUTION OF ARSENIC

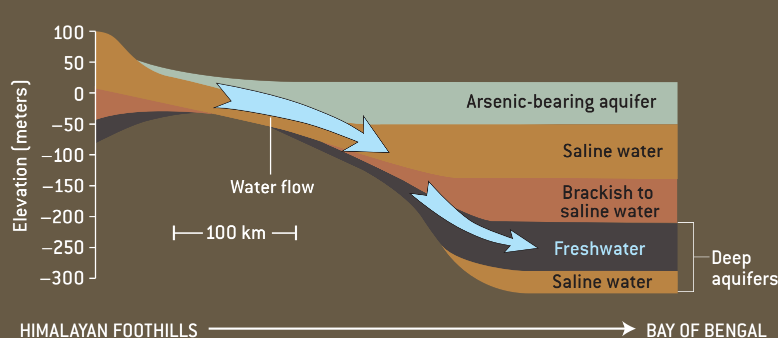
Arsenic is found in aquifers, usually underlying river deltas, around the world (*red areas at right*). In Bangladesh, arsenic levels are highest in the south (*bottom left*), presumably because the arsenic accumulated there when the Ganga and Brahmaputra rivers washed soil down from the Himalayas to the Bay of Bengal. The arsenic, which occurs in more recent, shallow deposits of clay, dissolves in underground water by processes that remain disputed. Aquifers deeper than 200 meters are believed to be free of the mineral (*bottom right*).

WORLDWIDE RISK

BANGLADESH



NORTH-SOUTH CUT THROUGH BANGLADESH DELTA



LUCY READING AND JANA BRENNING; SOURCE: "ARSENIC CONTAMINATION IN SOUTH-EAST ASIA REGION: TECHNOLOGIES FOR ARSENIC MITIGATION," BY M. FEROZE AHMED IN THE WORLD BANK GROUP'S "WATER WEEK 2004" FORUM

TWO WIVES of Abdul Rahman, the bedridden Haliman—a victim of the arsenic epidemic—and her young replacement, Shazida, have no choice but to get along. Shazida runs the household and takes care of Haliman's children.

DILIP MEHTA *Contact Press Images*

scarcely believe that their health problems arose from their precious tubewells. To ensure their cooperation, BRAC trained about 160 village women, even some who were illiterate, to test tubewell water using field kits. The volunteers tested more than 50,000 tubewells, painting red those that gave more than 50 micrograms of arsenic per liter and green those that gave less. We confirmed that they had identified 85 to 90 percent of the wells correctly. In some villages, all the tubewells turned out to be poisoned. In others, none were. Peculiarly, one tubewell might prove dangerous, whereas another close by would be fine.

The volunteers learned to identify those with skin lesions and other obvious signs of arsenicosis and to distinguish the three stages of the ailment. They found approximately 400 victims, who were subsequently examined by doctors. About three quarters of the patients were in the initial stage, but only a few had developed cancer. Most—60 percent—were male, with an average age of 36 years. Some were as young as five. Observing the volunteers test tubewells and identify sufferers, everyone in the targeted villages became aware of this previously unknown problem.

The volunteers also worked closely with other community members and BRAC personnel to create maps that showed local sources of water—arsenic-free tubewells, ordinary wells, streams and ponds—that could possibly replace contaminated tubewells. We then tested various systems with an eye toward safety, efficacy, cost and social acceptability. Broadly, these options were water from ponds, rivers and wells treated to remove pathogens; rainwater; groundwater treated to remove arsenic; piped water; and water from very deep aquifers. Over the past few years, we have learned much about which solutions might work on a national scale. (In recognition of its contributions toward the health and development of the poor, BRAC recently received the Gates Award for Global Health, a sum of $1 million.)

Compelling reasons exist for promoting the use of surface water. It is plentiful and generally free of arsenic, down to a depth of 10 meters. Historically, the people of Bangladesh drank water from designated clean ponds. With the advent of tubewells, these ponds were neglected, filled up for building or diverted to fish culture. The pond sand filter—a sand-based system installed on the bank to remove mud and pathogens—aims to revive the use of such ponds. Unfortunately, the bacterial load is so high that although the filter reduces it by two orders of magnitude, the water still contains some contaminants. The main obstacle to this filter, however, is that most of the ponds are now employed for fish culture, and they contain toxic chemicals used for killing predatory species (before fry are released). The biocides dissipate, but the water remains unsafe for human consumption. Moreover, the community must commit to cleaning the filter every few months.

Ordinary wells also use surface water, in this case collected from within a deep hole; it normally contains few pathogens but can get contaminated with fecal matter. In contrast, rainwater is pure but not available year-round. We once thought the so-called three-pitcher method to be a brilliant idea; this simple household device filters tubewell water through two earthenware pots—containing sand, charcoal and, most important, iron chips for binding arsenic—so that safe water collects in the third pot. But the contaminated shavings need to be disposed of periodically, which is yet another problem. Larger-scale arsenic filters are expensive, and they, too, must be cleaned of poisonous sludge.

In conversations with villagers, we realized that although they want arsenic-free water, they do not want to feel that they are going back in time to methods they once discarded. Tubewells had fitted nicely with their forward-looking aspirations. In my view, any successful method must embrace this sentiment. The two options that meet this criterion are piped water and deep wells.

Over the past few years, BRAC and other organizations have implemented a pilot program to pipe water, treated at a centralized facility, to villages. People welcomed it. A recent study by BRAC, in collaboration with the World Bank, found

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that villagers are even willing to pay part of the cost for installation. Nevertheless, the price remains prohibitive, and implementing such a program more broadly requires organization. If Bangladesh decides to move ahead with such systems, even on a limited scale, the local government must be charged with maintaining them in conjunction with nongovernmental organizations.

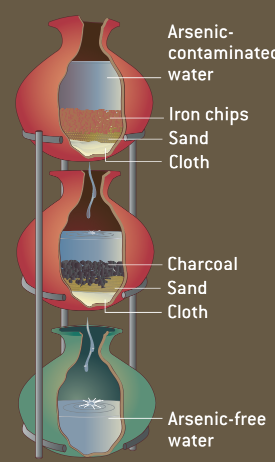
The long-term solution might instead lie in deep tubewells, which extract water from aquifers 200 meters or farther underground. Much of Bangladesh consists of two overlying freshwater aquifers, a shallow one (which reaches down as far as 70 meters) separated from a deeper one by layers of clay. Geologists agree that the risk of arsenic in deep aquifers is low, but before a few million such tubewells are dug, they need to be absolutely sure. Moreover, the drilling process needs to be refined so that the deeper aquifers are not poisoned by arsenic-bearing water trickling down from the shallow aquifers through the boreholes themselves.

Such drilling technology is untested, and digging these wells will require expert guidance. Murphy's Law—if anything can go wrong, it will—seems to apply with particular vengeance in developing countries, as the arsenic problem itself indicates. So the risk of inadvertently contaminating the deep aquifers must be carefully weighed.

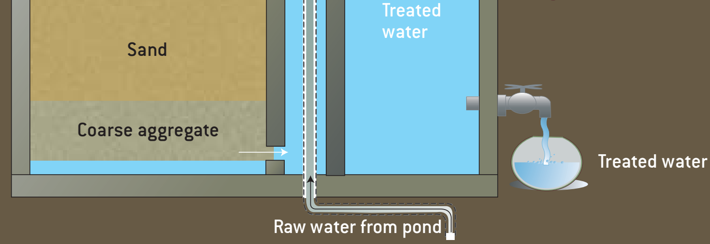
CHEAP SOLUTIONS FOR SAFER WATER

No perfect technology exists for providing safe water to poor communities plagued by the arsenic problem. Surface water in Bangladesh is free of arsenic but highly compromised by disease agents. The pond sand filter reduces the pathogens in pond or river water by two orders of magnitude—which is not enough. The three-pitcher method is simple and cheap: it removes arsenic from tubewell water by passing it through iron shavings. Unfortunately, disposing of the contaminated sludge is a problem for all arsenic filters, including larger, commercial varieties.

THREE-PITCHER FILTER



POND SAND FILTER



LUCY READING; SOURCE: SHARIAR SHAMS, WITH MODIFICATION BY MOHAMMAD JAKARIYA *BRAC*

Money Matters

RESEARCHERS AT Columbia University recently estimated that approximately $290 million will fund an integrated five-year testing, mitigation and monitoring program for arsenic all over Bangladesh. This amount, which envisages a deep tubewell in each of the country's 86,000 villages, is not too large for the benefit that will accrue, but it may be more than Bangladesh alone can afford.

Even if the money can be found, choosing and implementing a permanent solution to the arsenic problem will take several years. And Bangladesh cannot afford to wait. The country must immediately embark on a project to identify patients and provide them with safer water, in whatever way is locally feasible. In addition, we need to test every tubewell in the country. Despite everyone's best efforts, at the current rate of testing it could take several years to cover the entire nation.

In truth, even the poorest nations—perhaps especially the poorest—should check the quality of their water constantly. Ignoring this imperative is what landed Bangladesh in this predicament in the first place. Monitoring—not only for arsenic but also for manganese, fluoride, pesticides, other chemicals and pathogens—must become routine in all regions of the world where people drink water from underground. SA

MORE TO EXPLORE

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