Home wrecker. Gouchan and Renubala Ari lost their son and daughter-in-law to skin cancer attributed to drinking arsenic-contaminated water.

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TOXICOLOGY

A Sluggish Response to Humanity's Biggest Mass Poisoning

Arsenic-laced water has sickened thousands in South Asia. After delays and false starts, India is addressing the problem with a $500 million safe-water initiative

CHANDALATHI, INDIA—Until the mid-1990s, the biggest foe of Gouchan and Renubala Ari and their extended family was poverty. Then a more insidious menace began to stalk the Ari home in Chandalathi, a cluster of mud huts on the edge of a yellow mustard field some 60 kilometers north of Kolkata. The first signs of trouble were brown spots on their hands and feet that, as the months passed, developed into thick calluses and lesions. It was several years later that doctors visiting the area recognized the hallmark symptoms of arsenic poisoning.

Tests confirmed that water from the well the Aris were using was laden with arsenic. Their oldest son and his wife were diagnosed with skin cancer, a disease linked with chronic low-level arsenic exposure. Gouchan sold his cow, goats, and ducks to pay for their treatment. The couple died anyway. Afraid of suffering the same fate, two younger sons moved to other parts of India. "Arsenic destroyed our home," says Gouchan, a frail 76-year-old who walks with a limp because of arsenic lesions. "I'm tired of showing my calluses to strangers," adds Renubala. "Who can understand our misery?"

Thousands of families in the state of West Bengal have been affected by this blight. More than 40 million people here live in areas with elevated levels of naturally occurring arsenic in the groundwater. Authorities estimate that 5 million in West Bengal drink water with arsenic concentrations above the government standard of 50 micrograms per liter. In neighboring Bangladesh, more than 82 million people live in contaminated areas. And the problem is widening: In recent years, researchers have found high levels of groundwater arsenic in several other Indian states, including Uttar Pradesh, Bihar, and Manipur.

Although there are no reliable statistics on arsenic victims in India and Bangladesh, one research group has counted at least 14,000 cases of arsenicosis in West Bengal alone. The arsenic scourge, says Allan Smith, an epidemiologist at the University of California, Berkeley, is the "largest poisoning of a population in history."

Mark of a killer. Renubala's palms bear the brown calluses that are a hallmark symptom of arsenicosis.

It didn't have to turn out this way—certainly not in India, whose government frequently touts the country's burgeoning science and technology capacity. Here in West Bengal, officials have had a quarter-century to tackle the contamination. (Bangladesh learned of the threat a decade later.) Yet the government failed to investigate it adequately or provide alternative water resources to affected areas, critics charge. "For many years, government officials accused us of lying and exaggerating the problem," says dermatologist Kshitish Saha, who uncovered the first cases of arsenicosis while at the School of Tropical Medicine in Kolkata.

Since the early 1990s, when Indian authorities began to respond more vigorously to the crisis, state and national governments have pumped tens of millions of dollars into solutions aimed at providing safe water. The results have been lackluster. A $7 million initiative to fit wells with arsenic filtration units failed because of improper maintenance. Another strategy—drilling deep wells that bypass arsenic-tainted aquifers—has produced mixed results.

The most deplorable aspect of the tragedy, critics say, is that Indian officials have resisted educating villagers about the threat, partly out of concern that this could lead to societal unrest. This is unconscionable, says Dipankar Chakraborti, an environmental scientist at Jadavpur University (JU) in Kolkata. "If people are made to realize the dangers of drinking arsenic-contaminated water, they will take care of their own safety," he says.

West Bengal officials acknowledge that the state erred. But they say that a half-billion-dollar initiative now under way to install eight surface-water treatment plants and 360 high-capacity, deep wells fitted with arsenic-removal facilities will provide a long-term remedy to what ranks as one of the biggest public health disasters of the modern world. "Yes, there have been

delays," says D. N. Guha Majumdar, a gastroenterologist on West Bengal's arsenic task force. "But the government is acting now."

Shallow reactions

Until the mid-1960s, much of West Bengal relied on untreated water from ponds, rivers, and open wells; as a result, cholera and other lethal waterborne diseases took a heavy toll. A savior arrived in the form of shallow tube wells, pipes bored into the ground with a hand pump at the top. When the technology for sinking this sort of well became affordable, the government and private citizens began installing them by the thousands. Deaths from infectious diseases fell sharply.

But the tube wells spawned a new epidemic. After Saha first linked brown calluses to groundwater arsenic in 1982, the local government appointed a panel to examine the problem and find countermeasures. Over the next 5 years, teams from the School of Tropical Medicine, the All India Institute of Hygiene and Public Health, and other institutions documented evidence of chronic toxicity among hundreds of villagers in six districts of West Bengal.

Although some experts early on blamed the illnesses on industrial pollution, it soon became clear that the culprit was arsenic in alluvial aquifers. Researchers studying the phenomenon—seen in many other countries, including China, Vietnam, Chile, and the United States—now believe that soil microbes liberate arsenic from harmless pyrites in the alluvium. Open wells, even in arsenic-rich areas, typically have low arsenic concentrations because when the water stands exposed to air for days, the metal binds to iron oxides and other compounds and precipitates out of the water column. This does not happen in an enclosed tube well.

The crisis persuaded Chakraborti to give up a career in the United States and return to his Kolkata roots in 1988 to found the School of Environmental Studies at JU. Over the next 6 years, he and his group tested hundreds of tube wells, as well as skin, hair, nail, and urine samples. They found that arsenic contamination was widespread. In some areas, the government dug deep wells. But officials disputed the magnitude of the problem and ignored calls from Chakraborti and others to harness West Bengal's plentiful surface-water resources for a long-term solution.

Frustrated, Chakraborti took off his gloves. (It is easy to mistake the pugnacious scientist for an activist. He once scolded the state's environment minister for smoking at a meeting; on another occasion, he advised a prominent arsenic researcher to take a course in water testing.) Chakraborti organized an international conference at JU in February 1995, at least in part, he says, to embarrass officials into action (*Science*, 11 October 1996, p. 174). He put victims front and center. "I had 19 arsenic patients sitting in the first row," he says. Seventeen have since died.

The 1995 conference made Chakraborti persona non grata to the state government: He says he has been shut out of government-sponsored meetings and accused of being a traitor. But the event had an impact. The next year, West Bengal officials requested $200 million from the national government for countermeasures, receiving less than half of the request. Part of the money expanded an initiative to sink deep tube wells in an effort to tap untainted water below the alluvial aquifers. And in 1998, West Bengal began equipping 2400 hand-pumped shallow tube wells with arsenic-removal units: $1500 adsorption towers packed with substances such as alumina or iron oxide granules. The state also began building a surface-water treatment plant in Malda, one of the worst-affected districts.

For Chakraborti, this was not enough. Between 1999 and 2005, he and his colleagues evaluated the performance of nearly 600 of the hand-pumped arsenic-removal units. They uncovered numerous problems. Fifty units had been installed in areas with potable groundwater, while 73 were delivering water with arsenic concentrations above the permissible limit. And some 175 units allowed water through with unacceptable levels of iron. "Overall, the study showed that 82% of the [units] were not useful," the researchers reported last year in the *Water Quality Research Journal of Canada*. They blamed it on a lack of maintenance, including a failure to periodically replace adsorption media.

West Bengal officials dispute Chakraborti's analysis. Amiya Banerjee, chief engineer of the state's Public Health Engineering Directorate, claims that 70% of the installed arsenic-removal units are working fine. But he acknowledges that they are not being maintained well. Even before Chakraborti's study came out, the West Bengal government in early 2006 announced that it would no longer equip hand pumps with arsenic-removal units. "We realized that the government cannot oversee the maintenance of these units," Banerjee says.

Chakraborti's group has also assailed the government's strategy for boring deep tube wells indiscriminately. In the past 10 years, the researchers have found that at least 20 deep wells—100 to 150 meters deep—in West Bengal's North 24 Parganas and Murshidabad districts have gone from having virtually no arsenic in the water at the outset to concentrations ranging from 50 to 150 micrograms per liter (exceeding the 50-microgram limit) within 7 years. Even now, people seem blind to the risks: In interviews with *Science*, some villagers in North 24 Parganas district said they trusted that the water they drink from one of these wells is safe. Chakraborti argues that deep tube wells should be sunk only in areas where there is a thick clay barrier between the shallow, arsenic-contaminated aquifer and the deeper aquifer being tapped. "Subsurface geology should guide the strategy," he says.

Others disagree. Alexander van Geen, a geologist at Columbia University, is a strong advocate of deep tube wells as a short-term solution in Bangladesh. He says that mechanical failure of the wells, not arsenic leaching into deeper aquifers, is to blame for the handful of tainted wells. "Because of flawed construction, you end up drawing the shallow water," says van Geen, whose team has documented four such failures out of 51 deep tube wells monitored over 5 years in the Araihazar region in

CREDIT: ADAPTED FROM A MAP BY JEROME METRAL *ET AL.*, BASED ON DATA FROM SOES, JADAVPUR UNIVERSITY

Bangladesh. Although he agrees with Chakraborti's push for surface water as a long-term solution, van Geen says deep tube wells, regularly monitored, are "hard to beat" as a source of safe water over the next 10 years.

Technical fixes may be debated, but nobody disputes the need for better public awareness. Years ago, the West Bengal government decided to paint tube wells with potable water blue or green and leave unsafe tube wells unmarked—rather than paint them red, as suggested by the government's arsenic task force. "The administration thought that would create unnecessary panic," says Chandan Sengupta, a task force member who formerly managed a UNICEF project aimed at tackling the arsenic problem. When JU researchers in the mid-1990s took it upon themselves to paint unsafe wells red, Chakraborti says, "one legislator had the tube wells painted green and went around with a loudspeaker telling villagers that the water in them was fine."

Overcoming inertia

The headquarters of West Bengal's Public Health Engineering Directorate is located on the sixth floor of a dull high-rise in the heart of Kolkata. Dim stairwells are splattered with red marks from people spitting *paan*, a popular snack consisting of fragrant condiments wrapped in a leaf. Hallways throng with vendors making tea on little kerosene stoves. In a large, open office room, desks are covered with mountains of paper, but many of the directorate's clerks and mid-ranking employees are nowhere to be seen. Across the hall, aides stand guard outside the private offices of senior officials, such as chief engineer Amiya Banerjee.

Banerjee says that the government's handling of the arsenic crisis is now robust. "We knew all along that surface water had to be the long-term solution, but we needed a quick fix in the interim," he says, referring to the deep tube wells and arsenic-removal units for hand-pumped wells. Banerjee also defends the decision not to paint unsafe tube wells red, explaining that doing so would likely have deterred villagers from drawing water for safe uses such as washing.

In any case, Banerjee says, the government is now implementing long-term solutions. Groundwater will continue to be the mainstay. Under a $500 million initiative funded jointly by the state and national governments, West Bengal is sinking 360 large-diameter deep tube wells equipped with arsenic-treatment facilities to pipe water to 70% of the affected population. Government engineers will supervise maintenance of the treatment plants, Banerjee says.

Chakraborti contends that fitting each well with an arsenic-treatment plant is a waste of money, considering that only a small percentage of wells is likely to become contaminated. Van Geen too labels the plan as flawed. "Instead of setting up the treatment plants right away, it makes more sense to design a pumping system that could be connected to an arsenic-treatment module in the future if the need arises," he says. If the government is determined to install large arsenic-treatment plants, he argues, it would be wiser to purify water from shallow, contaminated aquifers and conserve the deeper, arsenic-free aquifers for future use.

Also under the West Bengal initiative, five surface-water treatment plants are being built. Together with three plants already commissioned in North 24 Parganas, South 24 Parganas, and Malda, they will serve 30% of the affected population. To pay for operating costs, the government will charge families a connection fee and about $1 a month. That's a risky strategy. Indian villagers typically don't pay for water, which officials acknowledge makes it difficult to get them to switch from a public tube well to a piped water connection. In the 3 years that the South 24 Parganas plant has been in operation, only 25,000 out of the 300,000 homes intended to be covered by the plant have taken a connection.

Other efforts under way include the distribution of cheap domestic filters and a drive to ensure that all 600,000 private tube wells are tested for arsenic. Majumdar of West Bengal's arsenic task force expects that everybody in West Bengal will have safe drinking water within 3 years.

Chakraborti is not as optimistic. And he wonders how many more people will suffer if awareness is not made an urgent priority. On a recent visit to Nadia district, he met a man with classic arsenicosis lesions who had never heard about arsenic before doctors diagnosed his disease last December. "This man drank contaminated water for years and then had to sell his land to find out what he was suffering from," Chakraborti says. "What is happening here is a grave injustice."

–YUDHIJIT BHATTACHARJEE

Defunct. Numerous arsenic-removal units installed by the West Bengal government no longer work due to lack of maintenance.

CREDITS: JEN DIMASCIO

A Young Scientist Shaped by Adversity

KOLKATA—First his uncle succumbed. Then his father, then his aunt. In 2004, when Kartik Biswas saw his mother, Dulali, develop the same lesions that presaged the deaths of his other family members, he took a 5-hour ride by bus and train from his village in Nadia district to Kolkata to seek out Dipankar Chakraborti, a crusading arsenic researcher at Jadavpur University. The encounter changed Biswas's life.

Chakraborti helped get Dulali admitted to a government hospital. Tests confirmed arsenicosis, and she underwent a skin graft on her palm. After bringing his mother home, Biswas spread the word on arsenic—for instance, by advising villagers which tube wells had tested positive for arsenic in Chakraborti's lab—and collected water samples for further testing. In 2005, Dulali got sick again and was diagnosed with skin cancer. Doctors amputated her arm, but the cancer had already spread, and she died last October.

This fall, Biswas, who is completing a master's degree in geography at a local college, will join Chakraborti's lab as a Ph.D. student to study countermeasures to groundwater contamination. Says Biswas, whose palms and feet bear the marks of mild arsenicosis, "Nobody should have to see their mother suffer like I did."

–Y.B.