Dealing with Arsenic Contamination in Bangladesh

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What do you think of when you hear the phrase "environmental disaster"? You may recall the 1986 nuclear meltdown at Chernobyl or the 1984 gas leak in Bhopal, India. These incidents were certainly grave—they affected countless numbers of people, killing thousands and leaving many others with long-term health problems. What may be surprising, however, is that the world is currently experiencing an environmental catastrophe greater than either of these, perhaps greater than any ever seen before.[1] Drinking water arsenic poisoning in Bangladesh is a nearly unfathomable problem, putting an estimated 50 million people at risk of severe health consequences.[2] Moreover, it is due to poorly understood natural phenomena and has no obvious solution. Even worse, Bangladesh's economic, technological, and social situation makes any proposed solution very difficult to implement effectively. Unfortunately, if appropriate action is not taken soon, the next few decades may see up to 270,000 new cases of arsenic-induced cancers in Bangladesh.[3]

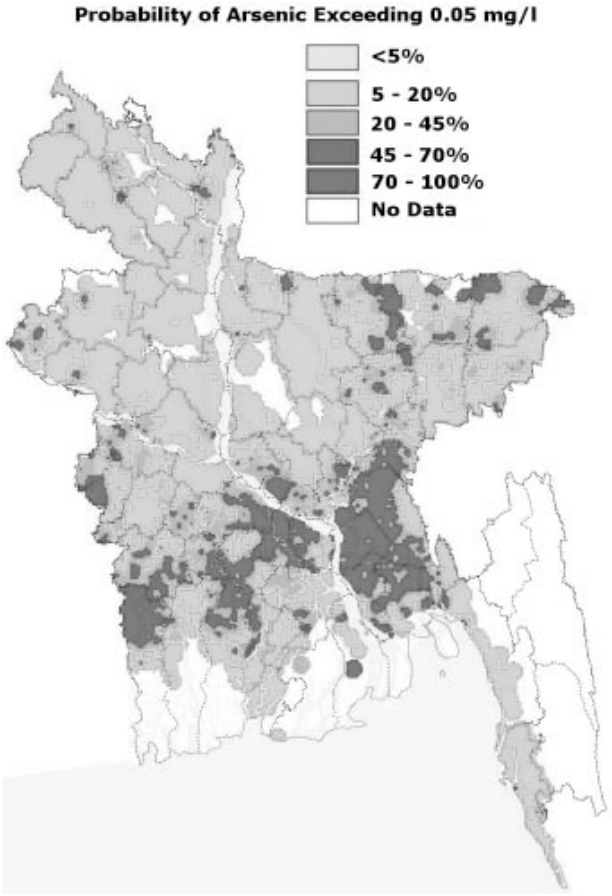

Figure 1. Levels of arsenic contamination in Bangladesh above the national standard of 50 ppb. Source: Medical Information Group (MIG), 1998.

Bangladesh's arsenic problems are fairly recent, dating to the 1970s at the earliest. The arsenic problem is an unintended result of a well-meaning effort to protect the country's people from water-borne diseases. In 1971, international aid agencies such as the United Nations Children's Fund (UNICEF), the World Bank, and the United Nations Development Program (UNDP) collaborated with private interest groups to install tubewells throughout the country.[4] Tubewells are 2-inch-wide metal pipes with attached hand pumps that are drilled deep (over 50 meters) into the earth in order to access groundwater from underground reservoirs. They were supposed to reduce Bangladesh's high child and infant mortality rates that resulted from water-borne diseases acquired from drinking stagnant surface water. Tubewell installation proceeded rapidly as the wells became an icon of better life for the poor; over the last 40 years, four million have been installed.[5] As originally expected, they have helped to significantly reduce child and infant mortality in Bangladesh (Figure 5). The country's infant mortality rate halved between 1960 and 1996, going from 247 deaths per 1,000 live births in 1960 to 112 deaths per 1,000 live births in 1996.[5] In comparison, Sweden has the world's lowest infant mortality rate at 3.47 deaths per 1,000 live births, and Angola has the highest infant mortality rate at 193.72 deaths per 1,000 live births.[6] Because tubewells helped decrease the rate so substantially, it was widely believed until recently that Bangladesh's well installation program was an incredible success.

Figure 2. Arsenic-induced lesions. Source: Arsenic in groundwater: testing pollution mechanisms for sedimentary aquifers in Bangladesh. J.M. McArthur, P. Ravenscroft, S. Safiullah, and M.F. Thirlwall.

Later it was discovered that well installation came at an unacceptable health cost. Arsenic poisoning was first discovered in West Bengal, India, in the 1980s. In 1993 arsenic-contaminated wells were also discovered in Bangladesh. Finally in 2000, the first comprehensive well-testing program was conducted in Bangladesh by the British Geological Survey.[4] Of the 2,022 wells tested, the survey found 35 percent to contain water with levels of arsenic above Bangladesh's standard of 50 parts per billion (ppb) (Figure 1). 8.4 percent of tested wells were found to contain water with over 300 ppb of arsenic, an unacceptably high level.[4] In contrast, the World Health Organization (WHO) proclaims that water with over 10 ppb arsenic is unsafe to drink.[7] According to a survey done by Bangladesh's Dhaka Community Hospital and the National Institute for Preventive and Social Medicine, 38 percent of water samples collected from 27 of Bangladesh's 28 districts were unsuitable for drinking by national Arsenic standards, while 58 percent were unacceptable by WHO standards.[2] The British Geological Survey, mentioned above, predicts similar results and estimates that 21 million people in Bangladesh are exposed to hazardous levels of arsenic in their drinking water.[7] The survey also estimates that a total of 1.5 million tubewells in Bangladesh contain water that does not meet the country's arsenic standards.[4]

The high levels of groundwater arsenic in Bangladesh can be blamed on the country's geology. Arsenic is widely distributed throughout the earth's crust. It enters water via the dissolution of minerals and ores and erosion of nearby rocks.[3] Levels of groundwater arsenic are especially high in South Asian and East Asian regions.[5] Although industrial materials contribute to arsenic levels in drinking water in some areas of the world, the problem in Bangladesh and neighboring West Bengal, India, appears to be purely geological.[2]

The arsenic found naturally in the earth comes in two major forms-organic and inorganic. The inorganic forms of arsenic, including arsine, arsenic-3, and arsenic-5, are very harmful to human health. They interfere with enzymatic function and gene transcription within the body's cells. Inorganic forms of arsenic are also difficult for the body to flush out, so they end up accumulating in the skin, bone, liver, kidneys, and muscle tissue. The organic forms of arsenic, however, are much less reactive and far less harmful than their inorganic counterparts. Moreover, after intake they are rapidly eliminated by the body as urine via the kidneys. Inorganic arsenic compounds, if metabolized by the body into organic forms, can also be excreted. Bangladesh's groundwater contains a mixture of both organic and inorganic arsenic. The water from contaminated tubewells, however, contains a higher proportion of inorganic arsenic than is deemed safe.[8]

Drinking water rich in inorganic arsenic over a long period leads to chronic arsenic poisoning, the health effects of which are referred to as arsenicosis.[9] The most common symptoms of long-term arsenicosis are lesions on the palms and soles of the feet (keratoses) and pigmentation changes on the upper chest, arms, and legs (Figures 2 and 4). Arsenic-induced lesions are wartlike structures that can grow to 1 cm in height. Aside from causing debilitating pain and, in extreme cases the inability to walk, these symptoms seem to be linked to skin cancer.[7] According to the International Journal of Cancer, "Arsenic may act as a co-carcinogen, not directly causing cancer, but allowing other substances, such as cigarette smoke or ultraviolet light, to cause mutations in DNA more effectively."[10] Although most commonly associated with skin cancer, arsenic in drinking water is also linked to a number of other types of cancers including cancer of the bladder, lung, and kidney. The International Program on Chemical Safety (IPCS) estimates the skin cancer risk due to lifetime consumption of arsenic-containing water to be 5 percent per 0.2 mg of arsenic per liter.[5] In other words, approximately one in 100 people who drink water containing 0.05 mg (50 ppb) arsenic per liter or more for a long period may eventually die from arsenic-related cancers.[9] If we assume that 21 million Bangladeshis have had long-term exposure to drinking water with over 50 ppb arsenic, then an estimated 210,000 arsenic-related cancer cases could arise in the near future. In reality the number should be even higher because people in several areas of Bangladesh are exposed to levels of arsenic far exceeding 50 ppb. This corresponds with the WHO's prediction that 200,000 to 270,000 deaths will occur in Bangladesh from arsenic-related cancers.[3]

Figure 3. Government poster warning the public about arsenic poisoning. Source: Radio netherland wereldomroep.

Although cancer and skin keratoses are major symptoms of long-term arsenic consumption, many other types of diseases might also result. These include hypertension and possible reproductive effects[11] (Figure 6). The intake of a high level of arsenic over a short

period of time causes acute arsenic poisoning. Its symptoms are vomiting, esophageal and abdominal pain, and bloody diarrhea. Unlike arsenicosis, which is a chronic disease, acute poisoning's effects do not persist following adequate treatment.[12]

In Taiwan, long-term exposure to arsenic in drinking water has been shown to cause "blackfoot disease," a severe malfunction of blood vessels that results in dry gangrene and amputation of afflicted extremities. Although blackfoot disease has only been observed in Taiwan, less severe forms of its symptoms have been seen elsewhere in the world.[11]

In Bangladesh it is predicted that about 100,000 people are currently suffering from arsenic-induced skin lesions.[3] Because the arsenic problem is still relatively new (most tubewells were dug within the past 20 years and it takes 20 years for most cancers to emerge) it is difficult to predict the long-term health consequences. According to David H. Kinley and Zabed Hossain of *World Watch*, "In parts of southern Bangladesh where arsenic levels are very high, one in ten adult deaths could be due to some form of arsenic-induced cancer."[4] The WHO agrees, saying that "over the next decade, skin and internal cancers are likely to become the principal human health concern arising from arsenic".[3]

A relatively easy treatment of acute arsenic poisoning is currently being developed by a number of institutions including the Intronaca Center for Arsenic Research in Bangladesh and research teams from MIT, Harvard, Columbia, and Texas A&M.[13] Treatment involves the elimination of inorganic arsenic from the patient's body by converting it to organic forms or chelating it to remove it from solution in the body's fluids. The organic and chelated inorganic arsenic is then readily excreted from the body by natural means.[14]

The Intronaca Center, with funding from the WHO and collaboration with U.S. and Bangladeshi academicians, is working with area hospitals to develop an agent that will remove arsenic from the body in that manner. They have found that giving patients antioxidants and vitamins, arsenic-free water, leafy vegetables, and high-protein foods lessens symptoms of acute poisoning.[14] Such treatment promotes the metabolism and excretion of inorganic arsenic. Surprisingly, it also relieves certain effects of chronic arsenicosis. For example, some patients with arsenic-induced keratosis of the skin, after undergoing many months of this treatment, reported some fading of their skin lesions and lessening of chronic body pains.[13] Still, this treatment is effective only during early stages of arsenicosis and acute arsenic poisoning. Once cancer sets in, all such remedies are futile.[14]

Figure 4. Arsenic-induced wounds on the feet. Source: Radio netherland wereldomroep.

The hope of the Intronaca Center and its associates is that testing for arsenic levels within the body can be done regularly throughout Bangladesh (Figure 9). Unfortunately, however, Bangladesh has a population of 132 million people and arsenic testing is quite complicated and expensive. Thus comprehensive testing of the entire population would simply be unfeasible; although less extensive testing and representative sampling tests can be performed, as is being done by Bangladeshi and foreign research teams and nongovernmental organizations (NGOs).[13] To test a patient's arsenic-intake levels, a sample of his/her urine is assayed for the concentrations and types of arsenic compounds it contains using a high pressure liquid chromatograph (HPLC). Because organic forms of arsenic are readily excreted by the body, a high level of arsenic in urine is indicative of successful metabolism and excretion of ingested arsenic.[15] The concentration of arsenic compounds in urine can be compared to that of the patient's regular drinking water source in order to estimate the amount of inorganic arsenic that remains lodged in the patient's body.[15] If levels are found to be high, the patient can be treated as described earlier.

Figure 5. Children waiting for water. Source: Radio netherland wereldomroep.

If arsenic testing is done regularly, and treatment is applied promptly when necessary, the patient's health will emerge relatively unscathed. He or she will not suffer the long-term consequences associated with untreated arsenic poisoning. Selective testing is occurring throughout Bangladesh in order to identify at-risk areas for arsenic and to selectively treat the people from these areas.[13]

Proposed solutions to the arsenic issue in Bangladesh are quite complex. This is partly because it is arguably the greatest ecological disaster witnessed in recent history. Thus, the technical hurdles standing between the problem and solution are immense. Perhaps more challenging, however, are the nontechnical

aspects of the problem. Bangladesh is one of the 20 poorest countries in the world. Many of the country's people have undergone immense hardships and are struggling to survive on the streets or in poor villages with inadequate health care and poor sanitary conditions. The life expectancy of Bangladeshis is only 62 years, and roughly half of the population lives in abject poverty.[16] Given the everyday hardships that they face, few Bangladeshis in areas with the highest groundwater arsenic levels have the luxury to think about possible future consequences. When one is struggling to survive every day, it is difficult to further inconvenience himself or herself by making the lifestyle changes necessary to avoid health problems that might occur 10 to 20 years down the road.

Figure 6. Bloodshot eyes are a sympton of arsenic poisoning. Source: Bangladesh Arsenic Photo Exhibition, World Bank Group.

A primary job for the Bangladeshi government, NGOs, and research teams has been building public awareness of the arsenic problem (Figure 7). The abundance of remote villages, slums, and homeless people make this a particularly difficult task. The government has compiled pamphlets that describe the terrible effects of arsenic poisoning and that explain how to obtain clean drinking water (Figure 3). These pamphlets have been distributed to NGOs and surveyors so that they can be read to villagers in the remotest parts of the country. Furthermore, NGOs and teams of researchers have frequented numerous at-risk villages, tested those with arsenicosis or arsenic poisoning, and taught the people how to obtain clean water.[13] Many of the techniques they are promoting to obtain clean water are very cheap and do not require large-scale government intervention. For example, straining water through a cloth after removing it from an arsenic-contaminated well and allowing the water to sit in the open for at least 24 hours afterward can remove up to 70 percent of the dissolved arsenic compounds. According to Dr. Mohammad Alauddin, director of the Intronaca Center, this simple treatment can, for example, reduce the arsenic content in drinking water from 200 ppb to 60 ppb, thus converting highly poisonous water to that containing a level of arsenic not far above the national standard.[13] Although 60 ppb is still not acceptable, it is better than the 200-ppb water coming directly from the well.

Airing out the water by letting it stand outside for several hours before drinking is a highly effective technique as the harmful inorganic arsenic compounds are readily converted to their far less harmful organic forms in the presence of oxygen.[15] Dugwells, which are shallow wells, would prevent the arsenic problem altogether because they are constantly exposed to the outside air. However, the unsanitary conditions in Bangladesh make any surface water unsafe to drink without considerable treatment due to water-borne diseases.[4] If dugwells are walled off and treated with mild bleaches, their water should be both sanitary and arsenic-free.[13]

Teams of researchers and NGOs, bearing in mind Bangladesh's poor economic situation, have explored many such inexpensive alternatives to the 1.5 million arsenic-rich tubewells strewn throughout the country. One solution that has already been implemented is the painting of tubewells. Recently, UNICEF supported Bangladesh's largest nongovernmental organization, BRAC, for the evaluation of over 161,000 tubewells serving several million people. BRAC workers used Merck-supplied kits to test the arsenic concentration of the water from each tubewell; they painted the tubewell handle green if it met Bangladesh's arsenic standard, and red otherwise[4] (Figures 8 and 10).

This approach has been highly effective as it indicates to people which wells are safe and which are unsafe, thus allowing them to switch from using red unsafe wells to green safe ones. The study shows that 88 percent of residents in Araihazar live within 100 meters of a safe well and 95 percent live within 200 meters of a safe well.[8] Thus it proposes that the safe and unsafe wells be distinguished from each other so that people can use only the safe ones for drinking water.[8] Wells with arsenic levels too high for drinking can still be used for washing clothes and bathing.[5] The study claims that well-switching, due to the high density of wells in Bangladesh, is a viable option in all but 29 of Bangladesh's 507 *upazilas*.[8]

Although a viable solution, the painting of tubewells and the promotion of well-switching has a few fundamental problems. The kits used to test the tubewells are not as dependable as they should be.[17] Accurate arsenic testing is technically difficult and expensive. Samples

Figure 7. A community gathering to educate the public about arsenic. Source: Bangladesh Arsenic Photo Exhibition, World Bank Group.

must be processed in an advanced water laboratory of which Bangladesh only has 13.[15] Regarding test kits, the Indian scientist Dipankar Chakraborti told *The Lancet* that "aid agencies are spending millions of dollars to buy arsenic test kits that have not been scientifically validated".[17] Chakraborti's comments came after he and his colleagues used flow injection hydride generation atomic absorption spectroscopy (FI-HG-AAS) to analyze 2,866 water samples that had been previously analyzed by aid agencies.[17] According to *The Lancet*, "Indian researchers have warned that hundreds of thousands of people in Bangladesh and India may be drinking arsenic-contaminated water because many wells may have been incorrectly labeled as safe by international agencies".[17]

There are also some socioeconomic and logistical factors that might limit the efficacy of well-switching proposals. Wells are typically near latrines and other private areas and are not meant to serve more than a handful of families.[8] Thus it may not be socially acceptable or viable to allow a large number of people to use the same tubewell. According to Green et al., however, in Araihazar "the density of users would not be as drastically altered as might be expected if each household with an unsafe well were to switch to the nearest safe well".[8] We must, however, note that this comment specifically pertains to Araihazar and not necessarily the rest of Bangladesh.

A related concern is the distance to safe wells and the role of women in Bangladeshi culture. In the villages especially, women typically do not leave their cluster of homes unaccompanied.[8] Thus an extra 100-meter walk from home to get to a safe well might stop women from collecting water altogether. Additionally, many of the people using the wells are extremely poor; the daily hardships they face make the drinking of arsenic-rich water the least of their worries. According to the WHO, "It has been found in Kenya that carrying water may account for up to 85 percent of total daily energy intake of females".[3] A number of physical ailments may result including neck and spinal problems.[5] Thus the poor and destitute—those who ultimately suffer most from arsenic-induced ailments—may not be able to walk the extra distance to drink from a clean well.

There are of course several alternatives to well-switching, which need to be implemented soon because there are several areas (29 *upazilas*) where the groundwater is so contaminated that well-switching is not an option. The harvesting of rainwater, commonly practiced in neighboring Thailand, has been proposed as a solution in these areas and elsewhere in Bangladesh.[4] The annual rainfall in Bangladesh is 1.5–2 meters per year in most areas, with eastern Bangladesh receiving up to 3.5 meters annually.[18] In districts with severely contaminated wells, the harvesting of rainwater is a cheap and clean alternative to the arsenic-contaminated well water.[13] Bangladesh's rainwater is also quite clean; unlike Europe and East Asia, Bangladesh gets very little acid rain.

Figure 8. A painted water pump. Source: Bangladesh Arsenic Photo Exhibition, World Bank Group.

Deep tubewells provide another source of clean water. According to the WHO, shallow tubewells (between 50 and 150 meters in depth) are most likely to contain arsenic-contaminated groundwater.[5] The arsenic levels from deep tubewells (greater than 200 meters in depth) and dugwells (20-30 meters) are much lower than that from shallow tubewells.[7] The British Geological Survey only found two of the 280 tested deep aquifers (depth greater than 200 meters) to be contaminated.[8] This notwithstanding, constructing a deep tubewell is difficult because the well must be drilled far into the ground. Moreover, it is hard to ensure that shallow aquifers above the deep aquifer do not leak into the deep tubewell.[8] This is major cause for concern: Bangladesh's capital city Dhaka, which has a population of roughly 10 million and has clean drinking water. Dhaka obtains much of its

Figure 9. A doctor checking a patient for arsenic-induced lesions. Source: Bangladesh Arsenic Photo Exhibition, World Bank Group.

Figure 10. Worker painting a water pump. Source: Bangladesh Arsenic Photo Exhibition, World Bank Group.

water from deep tubewells.[13] The implementation and use of deep tubewells might thus be a feasible option for the rest of the country as well.

Tackling the issue of arsenic contamination in Bangladesh is much more difficult than experts first predicted. Any proposed solution must take into account the socioeconomic status of Bangladesh and its residents. The technologies used in industrialized nations to treat drinking water and rid it of arsenic are not feasible in Bangladeshi villages. The government cannot afford such expensive water treatment facilities or even water piping systems for its 132 million residents. Thus cheaper options must be explored.

The major complication is the socioeconomic status of the Bangladeshi people. Roughly half of Bangladesh's population, or about 70 million people, live in absolute poverty.[16] They are struggling with very basic health problems such as starvation and volatile diseases arising from unsanitary conditions. Many Bangladeshis do not have the luxury of changing their lifestyle to prevent arsenicosis, whose onset does not generally occur until the person has been drinking arsenic-contaminated water for at least 10 years. Promoting simple lifestyle changes such as switching which wells people drink from may be more difficult than imagined. Building awareness and finding cheap, simple alternatives will have to be major pieces of any final solution to the arsenic problem.

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