Groundwater Arsenic Contamination in Bangladesh and West Bengal, India

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Nine districts in West Bengal, India, and 42 districts in Bangladesh have arsenic levels in groundwater above the World Health Organization maximum permissible limit of 50 µg/L. The area and population of the 42 districts in Bangladesh and the 9 districts in West Bengal are 92,106 km^2 and 79.9 million and 38,865 km^2 and 42.7 million, respectively. In our preliminary study, we have identified 985 arsenic-affected villages in 69 police stations/blocks of nine arsenic-affected districts in West Bengal. In Bangladesh, we have identified 492 affected villages in 141 police stations/blocks of 42 affected districts. To date, we have collected 10,991 water samples from 42 arsenic-affected districts in Bangladesh for analysis, 58,166 water samples from nine arsenic-affected districts in West Bengal. Of the water samples that we analyzed, 59 and 34%, respectively, contained arsenic levels above 50 µg/L. Thousands of hair, nail, and urine samples from people living in arsenic-affected villages have been analyzed to date; Bangladesh and West Bengal, 93 and 77% samples, on an average, contained arsenic above the normal/toxic level. We surveyed 27 of 42 districts in Bangladesh for arsenic patients; we identified patients with arsenical skin lesions in 25 districts. In West Bengal, we identified patients with lesions in seven of nine districts. We examined people from the affected villages at random for arsenical dermatologic features (11,180 and 29,035 from Bangladesh and West Bengal, respectively); 24.47 and 15.02% of those examined, respectively, had skin lesions. After 10 years of study in West Bengal and 5 in Bangladesh, we feel that we have seen only the tip of iceberg. *Key words*: arsenic in water, hair, nail, urine, skin-scale samples; arsenic-affected districts in Bangladesh and West Bengal, India; arsenical skin lesions; combat the arsenic crisis; estimated population drinking arsenic-contaminated water; groundwater arsenic contamination. *Environ Health Perspect* 108:393–397 (2000). [Online 16 March 2000]

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Approximately 20 incidents of groundwater arsenic contamination have been reported from all over the world. Of these, four major incidents were in Asia: in Bangladesh (*1–3*); West Bengal, India (*4–15*); Inner Mongolia, China (*16,17*); and Taiwan (*18–20*). The world's two biggest cases of groundwater arsenic contamination and those that affected the greatest number of people were in Bangladesh and West Bengal. The magnitude of the arsenic contamination in Bangladesh surfaced only recently (*3*). A recent report (*21*) described the magnitude of the arsenic contamination in Bangladesh; the World Bank's local chief stated that tens of millions of people are at risk for health effects and that 43,000 villages of 68,000 are presently at risk or could be at risk in future. In the same report, the World Health Organization (WHO) (*21*) predicted that, within a few years, death across much of southern Bangladesh (1 in 10 adults) could be from cancers triggered by arsenic. The British Geological Survey (*22*) analyzed 2,000 hand tube-well water samples from the eastern, southern, and western portions of Bangladesh, and reported that approximately 21 million people in Bangladesh were drinking water with arsenic levels > 50 µg/L. The U.S. Environmental Protection Agency (U.S. EPA) standard for arsenic in drinking water is 50 µg/L (*23*). The WHO maximum permissible limit for arsenic in drinking water is 50 µg/L (*24*). It was estimated that at the current EPA standard/WHO maximum permissible limit of 50 µg/L, the lifetime risk of dying from cancer of the liver, lung, kidney, or bladder from drinking 1 L water/day could be as high as 13 per 1,000 persons (*25*). The WHO recommended guideline value of arsenic in drinking water is 10 µg/L (*26*). In 1996, the WHO (*27*) reported that in 11 districts in Bangladesh, arsenic levels in groundwater were at higher concentrations in drinking water and that 23 million people were at risk. Those 11 districts with high arsenic concentrations have now become 42 districts.

We started our survey for arsenic-affected villages in 1989 in West Bengal. At that time we identified only 22 affected villages in 12 police stations/blocks of 5 districts. In subsequent years, we discovered more and more affected villages. Current statistics from our 10-year survey show that there are 985 arsenic-affected villages in 69 police stations of nine arsenic-affected districts. Even after 10 years, the more districts that we survey yield more affected villages that are added to our list.

We began our work in Bangladesh in 1995. At that time there were three affected villages in two police stations of two districts. Currently our list of arsenic-affected villages includes 492 villages in 141 police stations of 42 districts. Again, more villages are surveyed, and more arsenic-affected villages are discovered.

The apparent increase in affected villages is probably due to more arsenic monitoring and to illness surveillance over time. The physical parameters and the arsenic-affected areas of Bangladesh and West Bengal are shown in Table 1. Figure 1 shows the position of arsenic-affected districts in Bangladesh and West Bengal and the districts where we identified patients with arsenical skin lesions. Of a total of 18 districts in our preliminary survey in West Bengal, nine districts have arsenic levels > 50 µg/L in groundwater. Of those nine districts, seven contain people suffering from arsenical skin lesions. However, based on our water analysis report, we expected arsenic patients from all nine districts.

Our survey of all 64 districts in Bangladesh (to May 1999) showed 52 districts where the groundwater contained arsenic levels over the WHO guideline value (10 µg/L), and 42 districts where the level was > 50 µg/L. Of these 42 districts we have completed a preliminary survey in 27 districts to identify people with arsenical skin lesions; to date we have identified patients in 25 districts. We expect to find arsenic patients in all 42 districts. Even those districts in Bangladesh that presently appear safe may not remain safe in the long run. Until last year, we knew that the districts of Jamalpur and Bogra (Figure 1) had groundwater arsenic levels between 10 and 49 µg/L. In our recent survey, we found villages with high arsenic in groundwater in these two districts, and we also found very serious arsenic patients in Ezarapara (Jamalpur District) and Ullipur (Bogra District). These patients had

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severe spotted melanosis (n = 25), keratosis and hyperkeratosis (n = 23), and gangrene (n = 1). Twenty children younger than 11 years of age from these two villages also had arsenical skin lesions.

A detailed survey of Bangladesh and West Bengal is necessary to paint an accurate picture of arsenic contamination. Although the total population of the 42 districts in Bangladesh and the nine affected districts in West Bengal are approximately 80 million and 42 million, respectively, it does not mean that all of the individuals are drinking arsenic-contaminated water and will suffer from arsenic toxicity. However, they are undoubtedly at risk. To estimate the population that is drinking arsenic-contaminated water and suffering from arsenical skin lesions in West Bengal, we surveyed one of the nine affected districts [North 24-Parganas (Figure 1)] for 4 years. There are 22 police stations in North 24-Parganas; the district is 4,134 km^2 in total area and has a population of 7.28 million. We also surveyed in detail a few more police stations from other affected districts. We extrapolated our data for the nine affected districts and estimated that approximately 5 million people are drinking arsenic-contaminated water at levels > 50 µg/L and that nearly 300,000 people may have arsenical skin lesions. After we examined approximately 29,000 people from 200 villages in seven affected districts, we applied our theoretical calculations to our preliminary dermatologic field survey report. The comparative study indicated that we had not overestimated. We have not yet studied the data from Bangladesh in detail, but based on the analysis of our 4-year water and biologic samples and dermatologic study in the affected villages, we believe that Bangladesh is more affected than West Bengal (Table 1, Figure 1, Table 2, Figure 2). Although there have been some epidemiologic studies in West Bengal, (*14*), none have been done in Bangladesh to date. Thus, the actual public health burden of drinking water arsenic exposure in West Bengal and in Bangladesh are not yet known. Detailed epidemiologic research to characterize and quantify the arsenic-related public health burden is badly needed in these two areas.

Table 1. Physical parameters and arsenic-affected districts of Bangladesh and West Bengal.

Parameters	Bangladesh	West Bengal
Total area (km^2)	148,393	89,192.4
Total population (million)	120	68
Total number of districts	64	18
No. of districts with arsenic levels in groundwater > 50 µg/L	42	9
Area of affected districts (km^2)	92,106	38,865
Population of affected districts (million)	79.9	42.7
No. of districts with patients with arsenical skin lesions to date	25	7

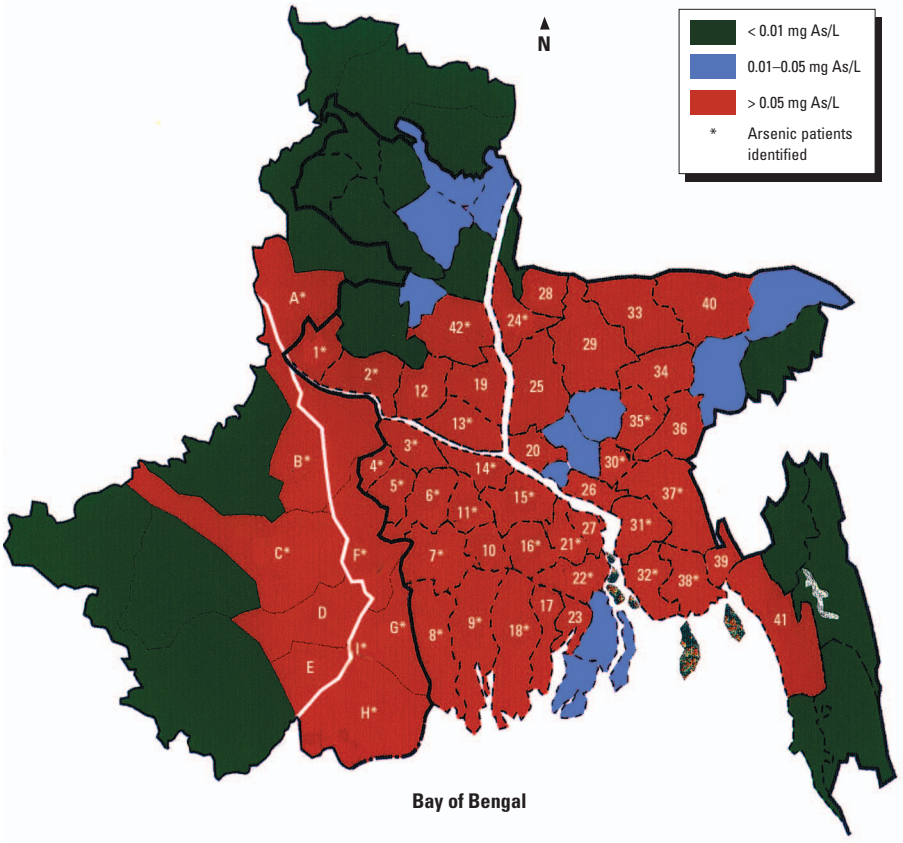

Figure 1. Map showing the arsenic-affected districts and the districts where arsenic patients have been identified in West Bengal and Bangladesh. Districts in West Bengal are indicated by letters, as follows: A, Maldah; B, Murshidabad; C, Bardhaman; D, Hugli; E, Howrah; F, Nadia; G, North 24-Parganas; H, South 24-Parganas; and I, Calcutta. Districts in Bangladesh are indicated by numbers, as follows: 1, Nawabganj; 2, Rajsahi; 3, Kushthia; 4, Meherpur; 5, Chuadanga; 6, Jhinaidah; 7, Jessore; 8, Satkhira; 9, Khulna; 10, Narail; 11, Magura; 12, Natore; 13, Pabna; 14, Rajbari; 15, Faridpur; 16, Gopalganj; 17, Pirojpur; 18, Bagerhat; 19, Sirajganj; 20, Manikganj; 21, Madaripur; 22, Barishal; 23, Jalkathii; 24, Jamalpur; 25, Tangail; 26, Munsiganj; 27, Shariatpur; 28, Sherpur; 29, Mymensingh; 30, Narayanganj; 31, Chandpur; 32, Laxmipur; 33, Netrokona; 34, Kishoreganj; 35, Narsingdi; 36, Braminbaria; 37, Comilla; 38, Noakhali; 39, Feni; 40, Sunamganj; 41, Chittagong; and 42, Bogra.

By May 1999, we had analyzed 12,135 and 58,166 hand tube wells for arsenic from 64 districts of Bangladesh and nine affected districts of West Bengal, respectively. Figure 2 shows a comparative study. Of the nine districts in West Bengal where we found arsenic in groundwater at levels > 50 µg/L, 45% of tube wells contained water that at present is safe to drink, and 55 and 34% of the tube wells contain arsenic above 10 and 50 µg/L, respectively. In Bangladesh, these values are 27, 73, and 59%, respectively, from 42 districts where groundwater contains > 50 µg/L arsenic. It appears that there is more arsenic groundwater contamination of higher concentration in Bangladesh as compared to West Bengal. Of the samples > 50 µg/L in 42 districts in Bangladesh (n = 10,991), the percentages of water samples with arsenic are 26.4, 10.8, 5.6, and 3.1% in the ranges 100–299, 300–499, 500–699, and 700–1,000 µg/L, respectively. In West Bengal, the samples > 50 µg/L arsenic (n = 58,166) have percentages of 14, 3, 0.7, and 0.2%, respectively. Groundwater samples containing > 1,000 µg/L arsenic are more abundant in Bangladesh: 233 samples of a total of 10,991 (from 42 districts) had arsenic levels > 1,000 µg/L. In West Bengal, only 38 of 58,166 samples are > 1,000 µg/L. Arsenic speciation of water samples indicated that monomethylarsonic acid and dimethylarsinic acid were not present in groundwater: the existing species were arsenate and arsenite.

To date, we have analyzed 3,332 hair; 3,321 nail; 1,043 urine; and 373 skin-scale samples from arsenic-affected villages in Bangladesh, and 7,135 hair; 7,381 nail; 9,795 urine; and 165 skin-scale samples in West Bengal. Approximately 60 and 20% of the samples (except skin scale) from Bangladesh and West Bengal, respectively, were from patients with arsenical skin lesions.

Table 2. Parametric presentation of arsenic in urine (metabolites), hair, nail, and skin-scale samples collected from the arsenic-affected areas of West Bengal and Bangladesh.

Parameters	Urine (μg/L)[a]		Hair (μg/kg)[b]		Nail (μg/kg)[c]		Skin scale (μg/kg)[d]	
	West Bengal	Bangladesh	West Bengal	Bangladesh	West Bengal	Bangladesh	West Bengal	Bangladesh
No. samples	9,795	1,043	7,135	3,332	7,381	3,321	165	373
Mean	180	495	1,480	4,050	4,560	9,250	6,820	5,730
Maximum	3,147	3,086	20,340	28,060	44,890	79,490	1,550	53,300
Minimum	10	24	180	280	380	260	1,280	600
Median	115	302	1,320	2,490	3,870	6,740	4,460	4,800
Standard deviation	268	493	1,550	4,040	3,980	8,730	4,750	9,790
Percent of samples with arsenic above normal/toxic level (hair)	89	95	57	81.2	83	93.7	–	–

[a]Normal excretion of arsenic in urine ranges from 5 to 40 μg/day (*28*). [b]Normal level of arsenic in hair ranges from 80 to 250 μg/kg; 1,000 μg/kg is the indication of toxicity (*29*). [c]Normal level of arsenic in nail ranges from 430 to 1,080 μg/kg (*30*). [d]There is no normal value in the literature for skin scale.

An analysis of these samples (Table 2) shows that 81, 94, and 95% of hair, nail, and urine samples, respectively, in Bangladesh and 57, 83, and 89% of the samples in West Bengal have arsenic levels above the normal levels for nail, urine, and toxic levels for hair samples. All skin scales contained elevated levels of arsenic. Many villagers may not be suffering from arsenical skin lesions but may have elevated levels of arsenic in hair and nails. Many more may be subclinically affected.

In West Bengal, we found arsenical neuropathy in 37.2% of 413 arsenicosis patients that we examined clinically. Eletrophysiologic study on 20 patients showed an affliction of the sensory nerves in nine patients (45%) and an affliction of the motor nerves in four patients (25%).

In the last 10 years, we completed a preliminary survey in 200 villages of seven districts of the nine arsenic-affected districts. This survey counted arsenical dermatologic features among villagers. We examined 29,035 people (including children) at random from the affected villages. We identified 151 villages where people were suffering from arsenic-induced skin lesions, and we registered 4,420 (15.02%) people with arsenical skin lesions. In Bangladesh, we found arsenic patients in 112 of the 118 villages that have been surveyed to date. These villages were from 27 districts of the 42 where groundwater arsenic levels were > 50 μg/L. We examined 11,180 people (including children) at random; we registered 2,736 (24.47%) people with arsenical skin lesions. More people are suffering from arsenical skin lesions in Bangladesh than in West Bengal. In Bangladesh, 6.36% of the children examined from affected villages have arsenical skin lesions, whereas in West Bengal 1.7% of the children of a total of 6,695 examined have arsenical skin lesions. Children younger than 11 years of age normally do not exhibit arsenical skin lesions. Exceptions are found when the arsenic concentration in water is very high (≥ 1,000 μg/L) or when the arsenic concentration is low (around 500 μg/L) but the children get poor nutrition. Normally, we found arsenical skin lesions among adult villagers in West Bengal and Bangladesh when the water contained arsenic above 300 μg/L. The average water intake is 4 L/day for adults (*31*). However, if the nutrition status is poor, lower arsenic levels may cause arsenical skin lesions, and if the nutrition status is good, even 400 μg arsenic/L may not show skin lesions. We did not find people suffering from arsenical skin lesions who drank water with < 100 μg/L arsenic.

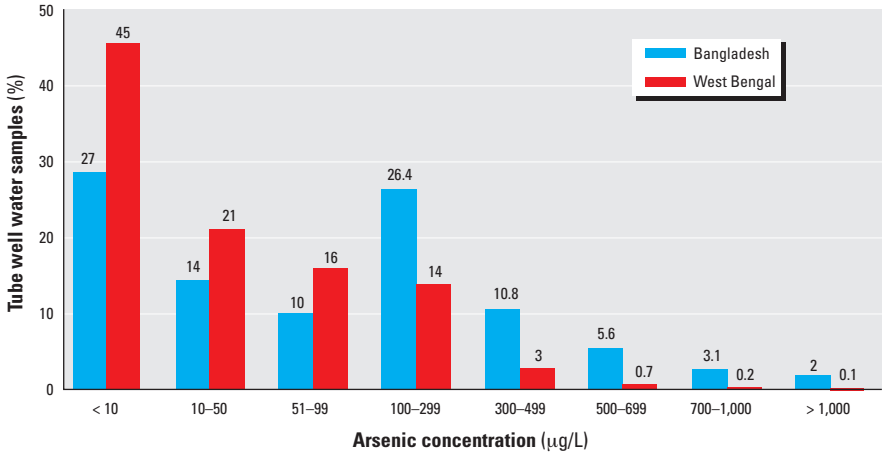

Figure 2. Comparison of the percentage of water samples in different concentration ranges (micrograms per liter) in nine districts in West Bengal (n = 58,166) and 42 districts in Bangladesh (n = 10,991).

Symptomatology of arsenical toxicity may develop insidiously after 6 months to 2 years or more, depending on the amount of water intake and the arsenic concentration in the water sample. The higher the concentration of arsenic in water and the higher the amount of daily water intake, the earlier one of clinical features may appear. Darkening of skin (diffuse melanosis) in the whole body or on the palm of the hand is the earliest symptom. People suffering from arsenic toxicity do not necessarily show symptoms of diffuse melanosis. Spotted pigmentation (spotted melanosis) is an early symptom that is common and is usually seen on the chest, back, or limbs. Leucomelanosis (white and black spots side by side) is also seen on many patients. Leucomelanosis is common in persons who have stopped drinking arsenic-contaminated water but who previously had spotted melanosis. Buccal mucus membrane melanosis (diffuse, patchy, or spotted melanosis) on the tongue, gums, lips, etc. may also be manifestations of arsenic toxicity. Keratosis is a late feature of arsenical dermatosis. Diffuse or nodular keratosis on the palm of the hand and the sole of the foot is a sign of moderately severe toxicity. Rough dry skin, often with palpable nodules (spotted keratosis), in dorsum of hands, feet, and legs are symptoms seen in severe cases. However, pigmentation or nodular rough skin alone may not confirm arsenic patients until hair/nail samples show elevated levels of arsenic, but a combination of pigmentation (melanosis) and nodular rough skin (spotted palmoplanter keratosis) in a victim is a sure sign of arsenic toxicity. Other symptoms of arsenic toxicity that are sometimes found are conjunctival congestion and nonpitting swelling (solid edema) of the feet. Complications such as liver enlargement (hepatomegaly), spleen enlargement (splenomegaly), and fluid in the abdomen (ascitis) are seen in severe cases. Squamous cell carcinoma; basal cell carcinoma; Bowen disease;

and carcinoma affecting the lung, uterus, bladder, genitourinary tract, or other sites are often seen in patients with advanced cases that have suffered for many years.

During our last 10 years of field experience in West Bengal and 4 years in Bangladesh, we have observed that those suffering from diffused melanosis and light spotted melanosis can recover after drinking safe water, eating nutritious food, and taking vitamins. Normally, diffused melanosis disappears easily after drinking safe water. However, if keratosis is appreciably visible, it may be reduced by drinking safe water and eating nutritious food, but it may not disappear. In arsenic patients with keratosis, the appearance of keratosis does not stop even after drinking safe water over a long period of time and even when hair, nail, and skin scales contain safe level of arsenic. Those suffering from severe keratosis may develop skin cancer in the long run (Figure 3). We are obtaining more information about arsenic patients dying of cancers other than skin cancer, such as lung, liver, and bladder cancer. With the present health service facilities in West Bengal and Bangladesh villages, it is difficult to diagnose internal cancers in those affected. The villagers cannot afford to travel to major cities for diagnosis without financial assistance. Figure 4 shows an arsenic patient with several keratoses and who died of lung cancer. We do not know how many people are suffering from internal cancers.

To combat the present arsenic crisis, we urgently need the following:

- In most of the villages surveyed in West Bengal and Bangladesh, an average of 35% of the tube wells contain water that is safe to drink. The mouths of the safe tube wells must be colored green and the unsafe ones red so that the villagers can use green tube wells for drinking and cooking, and red tube wells for bathing, washing, toilet, etc. The safe tube wells should be tested for arsenic every 3–6 months.
- Epidemiologic research is needed in the arsenic-affected areas of West Bengal and Bangladesh to characterize and quantify the arsenic-related public health burden and to document the long-term health benefits of arsenic exposure reduction.
- When groundwater was first extracted from the ground in the Nadia District of West Bengal during the 1960s, the people of the area left the village crying, "Devil's water is coming! Devil's water is coming!" They believed that because the water came from the ground it was tainted by the devil. Even now, many villagers believe that their skin lesions are due to curse of God or are the consequence of the wrath of God. The people should be made aware that their arsenic disease is due to the arsenic-contaminated groundwater they are using for drinking and cooking.
- In Bangladesh and West Bengal, the surface resources of sweet water such as rivers, wetlands, flooded river basins, and oxbow lakes are among the largest in the world. These two delta areas are known as the land of rivers and have approximately 2,000 mm annual rainfall. Proper watershed management and villager participation are needed to assist in the utilization of these huge bodies of water.
- We must understand that there is no medicine for chronic arsenic toxicity; safe water, nutritious food, and physical exercise are the only preventive measures to fight chronic arsenic toxicity. Seasonal fruits and vegetables are readily available in Bangladesh and West Bengal. However, the villagers cook the vegetables in such a way that their nutrition value is lost. The villagers are also reluctant to consume quantities of seasonal fruits. The villagers believe that it is necessary to eat fish, meat, and eggs for nutritious food. The elephant, the strongest animal, is a vegetarian.
- The scientific community and medical professionals all over the world must work to find a solution to the problem that has put more than 100 million people at risk in West Bengal and Bangladesh.

Figure 3. Squamous cell carcinoma on heel. The patient was from the village of Singerdanga (police station Gaighata), North 24-Parganas District.

Figure 4. Hyperkeratosis on sole. The patient died of lung cancer. The patient was from the village of Chandpur (rail line; police station Basirhat), North 24-Parganas District).

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