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**Drinking Death in Groundwater:  
Arsenic Contamination as a Threat to Water Security  
for Bangladesh**

*Mustafa Moinuddin*  
Embassy of Switzerland  
Dhaka, Bangladesh

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# **Drinking Death in Groundwater**

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## CONTENTS

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<i>About the Author</i>	v
<b>Executive Summary</b>	<b>1</b>
<b>Part One</b>	
<b>Bangladesh and Its Water Supply Scenario</b>	<b>3</b>
Bangladesh	3
Drinking Water Supply Scenario in Bangladesh	3
Evolution of Groundwater as the Main Source of Potable Water in Bangladesh	3
Use of Groundwater for Irrigation Purposes	4
Safe Water Supply and Development	5
<b>Part Two</b>	
<b>Groundwater Poisoning in Bangladesh</b>	<b>7</b>
The Discovery of Arsenic Contamination of Groundwater in Bangladesh	7
Sources of Arsenic: A Natural Origin?	8
<b>Part Three</b>	
<b>Drinking Death in Groundwater</b>	<b>11</b>
Arsenic Contamination as a Major Health Hazard in Bangladesh	11
Toxic Effects of Arsenic on Health	11
Social Costs of Arsenic Contamination	12
Arsenic in the Food Chain	13
<b>Part Four</b>	
<b>Arsenic in Groundwater Across the World</b>	<b>15</b>
<b>Part Five</b>	
<b>Facing the Challenge of Arsenic Contamination</b>	<b>19</b>
Identification of the Scale and Nature of the Problem: Screening the Tubewells	19
Increasing Awareness	19
Healthcare Options	21
Mitigation of Arsenic: Alternative Sources of Safe Drinking Water	21
<b>Part Six</b>	
<b>Recommendations</b>	<b>27</b>
The Need for a Concerted Effort	27
<b>Part Seven</b>	
<b>Concluding Remarks</b>	<b>29</b>



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The views expressed in this paper are those of the author, and do not reflect the views or position of the Embassy of Switzerland in Dhaka.





## EXECUTIVE SUMMARY

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Overstepping political boundaries, environmental problems are increasingly putting pressure on the people of the world. Bangladesh is not an exception in this regard. This densely populated low-income country of the South Asian region faces a plethora of environmental hazards, both natural and man-made. Floods, droughts, land degradation, and air pollution are constantly making the people of Bangladesh suffer. One of the major problems for the Bangladesh environment is its water. Pollution and water-borne diseases are common problems for the Bangladeshis. The Farakka Barrage in India plays a crucial role in the water security for Bangladesh. Scarcity of water in the dry season and excess flow of water during the monsoon are among the many critical water problems believed to be emanating from the aforesaid barrage in India. However, the discovery in the 1990s of arsenic in the groundwater of Bangladesh, the main source of drinking water for the country, has added a new dimension to the already existing water security problems in the country. With an estimated 35 to 57 million people drinking arsenic-contaminated groundwater from the hand tubewells installed over the last three decades, the country is now facing not only a major environmental problem, but also a critical health hazard. The World Health Organization (WHO) has identified the arsenic contamination in Bangladesh as the “largest mass poisoning of a population in history.”

Until the mid-1990s, the scale of the groundwater arsenic problem in Bangladesh was largely unknown. The first indications of a problem became apparent from a small number of tubewell water analyses from the western part of Bangladesh. By 1997 it was well recognized that in many areas of the country, groundwater, the main source of drinking water, is contaminated with arsenic above the permissible limit. Many of the millions of hand tubewells believed to be supplying pure drinking water are actually leading Bangladesh towards a critical health hazard. The country is now threatened by mass poisoning by arsenic, endangering the lives of millions of people, in both rural and urban areas.

The government of Bangladesh, donors, development agencies and non-governmental organizations (NGOs) came forward to try to solve this problem. They initiated a number of projects including screening and labeling of tubewells, building mass awareness about arsenic contamination, developing appropriate and cost-effective arsenic mitigation procedures, and identifying alternative sources of safe drinking water. However, the success so far is negligible. Several organizations proposed ideas on mitigation of arsenic from water, but the country has yet to find a “permanent” solution to the problem. Moreover, the masses, particularly in the rural areas, are largely unaware of the problem. Absence of alternative sources of drinking water has made finding a solution even more complicated.

This paper analyzes the nature, causes and consequences of arsenic contamination of groundwater in Bangladesh and the available mitigation options. The paper is divided into several parts. Part One looks at the geophysical and demographic aspects of Bangladesh and then at the drinking water supply scenario in the country. The second part of the paper devotes itself to discussing the background and origin of arsenic contamination in Bangladesh. Part Three analyzes the threat that the high level of arsenic in drinking water poses to the people, examining the consequences for health as well as on society and considers possible contamination of the food chain. In Part Four, the paper looks at occurrences of arsenic in other countries. Part Five reviews and analyzes ways to face the challenge of arsenic contamination. This part also documents some of the most-recommended options for the provision of safe drinking water. Part Six puts forward recommendations as to how to deal with the problem of arsenic in Bangladesh, how to find appropriate and cost effective safe water supply options and thus to ensure, at least partially, water security for Bangladesh. Finally, the concluding remarks in Part Seven advocate a definite role for the government of Bangladesh in combating the arsenic menace, but at the same time emphasize the involvement of local communities in any program related to arsenic mitigation. Moreover, it reiterates that in order to ensure drinking water security, the focus should not only be on the mitigation of arsenic, but the provision in general of safe drinking water that is free from any kind of contamination, be it biological or chemical.



## Bangladesh

Abutting India, Myanmar, and the Bay of Bengal, Bangladesh is a small country in the South Asian region with an area of 147,570 square kilometers. Geographically it is situated between 20°34' and 26°38' north latitude and 88°01' to 92°41' east longitude.<sup>1</sup> The nation, largely a flat delta, is transected by numerous rivers and their tributaries. A large number of other water bodies such as lakes, canals, and streams are also scattered around the country. The climate of Bangladesh is sub-tropical monsoon with a maximum average temperature of 34°C in summer and a minimum of 11°C in winter. The country receives heavy rainfall during the rainy season; the average annual rainfall varies from 1,194 mm to 3,454 mm.<sup>2</sup>

Despite possessing a small geographical area, Bangladesh has a relatively large population of 134 million people. Poverty is rampant, and the Gross Domestic Product per capita averages around US \$360. Most of the people do not have access to basic needs like food, education, adequate housing, and health services. The United Nations Human Development Program (UNDP) Human Development Index positions Bangladesh at 139 in the world.<sup>3</sup>

## Drinking Water Supply Scenario in Bangladesh

Even though Bangladesh is famous, from ancient times, for its abundance of water from various sources, one of the major problems that the country has been suffering for decades is the scarcity of safe drinking water. Prior to independence in 1971, surface waters from ponds, lakes, and rivers, and to a lesser degree, groundwater from dug wells, were the traditional sources of drinking water for the people of Bangladesh. In coastal areas, rainwater for drinking has also been used on a limited scale for a long time. Despite the abundance of surface water, there has always been the question of quality. The surface water sources are being misused as a sink for highly polluting wastewaters from domestic as well as industrial sources. Pollution loads far exceeding dispersion capacities cause severe degradation of water quality. This microbiologically unsafe surface water, with its bacteriological and fecal contamination, extracted a heavy toll on human lives. Every year, hundreds of thousands of people, particularly children, died of cholera, diarrhea, dysentery, typhoid, and other water-borne diseases.

## Evolution of Groundwater as the Main Source of Potable Water in Bangladesh

The poor surface water quality compelled the water supply authorities and agencies to develop a groundwater supply system in Bangladesh. After the independence of the country, in the early 1970s, the Department of Public Health Engineering (DPHE) of the government of Bangladesh, with assistance from the United Nations Children's Fund (UNICEF), embarked on a massive program to bore holes to tap into groundwater they believed would not be contaminated. The program sought to install hundreds of thousands of groundwater wells, known as tubewells, to provide safe drinking water for the people of Bangladesh. Initially, the community did not share any cost for sinking of tubewells; but in the course of time, to ensure improved maintenance, cost sharing principles were adopted for the program.<sup>4</sup> At present, there are approximately 4.5 million public tubewells (installed by government departments) as part of the total of 9 million tubewells in Bangladesh.<sup>5</sup>

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<sup>1</sup> Sirajul Islam, ed., *Banglapedia: National Encyclopedia of Bangladesh* (Asiatic Society of Bangladesh, March 2003).

<sup>2</sup> Ibid.

<sup>3</sup> United Nations, *UNDP Human Development Report 2003* (New York: Oxford University Press, 2003).

<sup>4</sup> M. Nuruzzaman, Abdul Quader Chowdhury, and Feroze Ahmed, "Arsenic Mitigation Strategy in Bangladesh," in *Report of the Specialized Course on Arsenic Contamination in Bangladesh* (Dhaka: International Training Network Centre [ITN] Bangladesh, May 18–23, 2002).

<sup>5</sup> Elizabeth M. Jones, *Arsenic 2000: An Overview of the Arsenic Issue in Bangladesh*, Draft Final Report (Dhaka: WaterAid Bangladesh, December 2000).

Bangladesh achieved a remarkable success, at least initially, through this tubewell initiative. An estimated 97 percent of the rural population received access to this bacteriologically safe tubewell water. This made a significant contribution to decreasing the infant mortality rate, halving it over a period of thirty-six years, from 151 per thousand in 1960 to 83 per thousand in 1996.<sup>6</sup> The under-five mortality rate also decreased significantly.

### Use of Groundwater for Irrigation Purposes

Apart from such domestic uses as drinking and cooking, huge quantities of groundwater, particularly from the shallow aquifer, are used for irrigation in Bangladesh. In the absence of adequate surface water in the dry season, irrigation becomes heavily dependent on groundwater. Between 30 and 40 percent of the net cultivable area of the country is under irrigation.<sup>7</sup>

**Table 1.1: Summary of Change in Use of Irrigation Technologies**  
(expressed as percentage of the overall irrigation volume)

Mode of Irrigation	1982–83	1996–97
<b>Groundwater</b>		
Shallow tubewell	24	56
Deep tubewell	15	13
Manual operated pump unit	1	1
<b>Surface water</b>		
Low-lift pump	22	15
Traditional	28	5
Canal	10	10

Source: D.G. Kinniburgh and P.L. Smedley, eds., *Arsenic Contamination of Groundwater in Bangladesh*, *British Geological Survey Report*, Volume 2 (Keyworth, Nottingham: British Geological Survey, 2001).

During the last decade and a half, irrigation coverage has been increased significantly to raise food production levels. The total area under irrigation coverage has risen from 1.52 million hectares in 1982–83 to 3.79 million hectares in 1996–97.<sup>8</sup> The increase is largely attributable to the installation of different types of irrigation wells, particularly shallow tubewells. According to the National Minor Irrigation Census 1996/1997, a total of 629,834 shallow tubewells, 25,210 deep tubewells, and 210 force mode tubewells are used for irrigation in Bangladesh.<sup>9</sup>

The proportion of irrigation water drawn from groundwater has changed significantly, too. The contribution of groundwater in relation to total irrigated area increased from 41 percent in 1982/83 to 71 percent in 1996/97 and to over 75 percent in 2001.<sup>10</sup>

<sup>6</sup> United Nations, *State of the Children's Report* (New York: UNICEF, 1998).

<sup>7</sup> S.M. Imamul Huq and Ravi Naidu, "Arsenic in Groundwater of Bangladesh: Contamination in the Food Chain," in *Arsenic Contamination in Bangladesh* (Dhaka: ITN Bangladesh, 2002).

<sup>8</sup> *National Minor Irrigation Census 1996/1997*, as quoted in *Arsenic Contamination of Groundwater in Bangladesh*, *British Geological Survey Report*, Volume 2, eds. D.G. Kinniburgh and P.L. Smedley (Keyworth, Nottingham: British Geological Survey, 2001).

<sup>9</sup> *National Minor Irrigation Census 1996/1997*, as quoted in Dr. M. Ashraf Ali, "Fate of Arsenic in the Environment," in *Arsenic Contamination in Bangladesh* (Dhaka: ITN Bangladesh, 2002).

<sup>10</sup> M.A. Ali et al., *Fate of Arsenic Extracted With Groundwater*, <http://www.unu.edu/env/Arsenic/Dhaka2003/02-Ali.pdf>.

### **Safe Water Supply and Development**

Access to a safe water supply is one of the most important determinants of health and socioeconomic development.<sup>11</sup> For human consumption, water should be both safe and wholesome. Without ample safe drinking water, communities cannot be healthy.<sup>12</sup> For a developing country like Bangladesh, where the majority of the people live below the poverty line, the provision of safe drinking water is one of the prior conditions for overall social development.

Water is considered “safe” when it is free from pathogenic agents, free from harmful chemical substances, and pleasant to taste—i.e., ideally free from color and odor, and usable for domestic purposes.<sup>13</sup>

Provision of safe water supply can result in direct health benefits in the form of improved nutrition and personal hygiene, as well as a reduction in water-borne disease. Again, in many of the developing countries, including Bangladesh, primarily women and girls engage in collecting water. A more convenient water supply system can decrease their weight-bearing responsibilities, which has a considerable health benefit. These health benefits can also contribute to a greater work capacity and thus towards increased production and overall economic development.

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<sup>11</sup> B. Cvjetanovic, “Health Effects and Impact of Water Supply and Sanitation,” *World Health Statistics Quarterly* (1986).

<sup>12</sup> World Health Organization, *Towards an Assessment of the Socioeconomic Impact of Arsenic Poisoning in Bangladesh*, (Geneva: WHO, 2000).

<sup>13</sup> K. Park, *Text Book of Preventive and Social Medicine*, 15<sup>th</sup> ed. (Banarsidas Bhanot Pub. India, 1997).



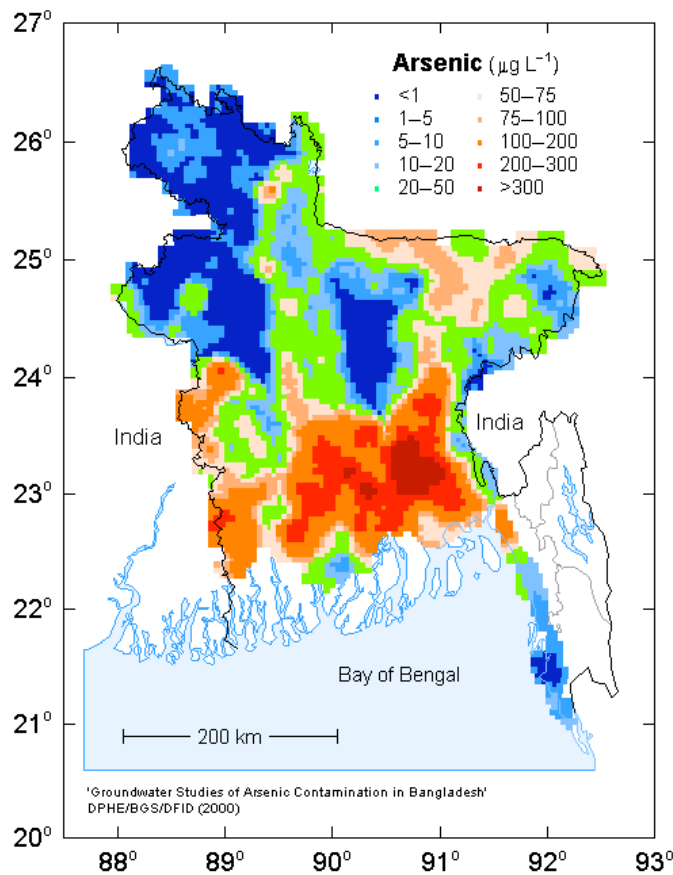
PART TWO

Groundwater Poisoning in Bangladesh

The Discovery of Arsenic Contamination of Groundwater in Bangladesh

The supply of pure drinking water to at least 97 percent of the people of the country has been one of the few success stories in public health care in Bangladesh. The success, however, was compromised by reports of arsenic found in the groundwater from tubewells in many parts of the country. In the early 1990s, arsenic—the new menace—shattered the notion of tubewell water as “safe.”

Figure 2.1: Map of Bangladesh Showing the Regional Distribution of Arsenic in Groundwater



Source: British Geological Survey, 2001, <http://www.bgs.ac.uk/>.

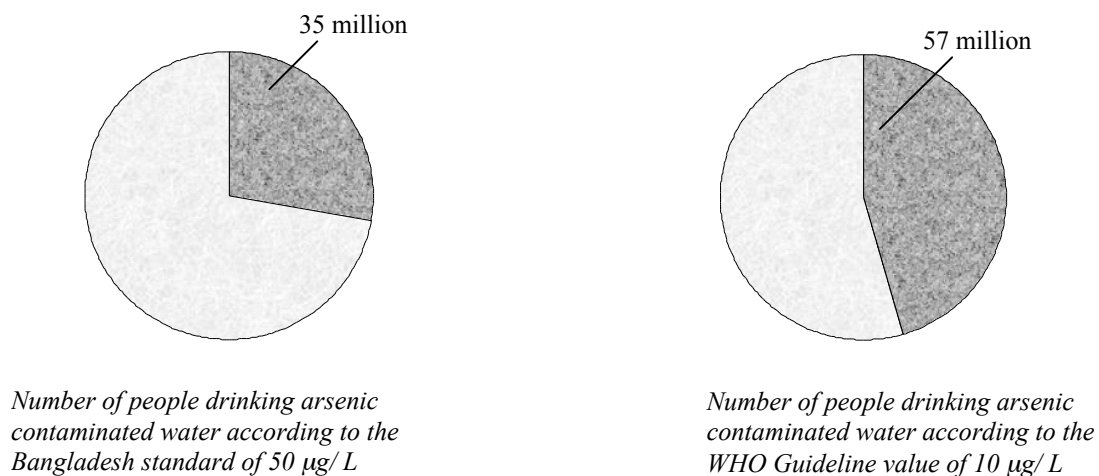
Arsenic as a public health problem was first identified in West Bengal, India, where the geological formations, economic conditions, food habits, and tubewells are similar to those in Bangladesh.<sup>14</sup> In the early 1990s, people started to develop arsenicosis, the disease caused by arsenic, in the arsenic-affected zones of

<sup>14</sup> “Search for Cleaner Water Causes Major Problems with Arsenic in Bangladesh Public Water Supply,” in *Civil and Environmental Engineering at MIT* (the newsletter of the Civil and Environmental Engineering Department at Massachusetts Institute of Technology), winter 2002, [http://web.mit.edu/civenv/html/people/alumni\\_newsletters/winter\\_02/art5.htm](http://web.mit.edu/civenv/html/people/alumni_newsletters/winter_02/art5.htm).

West Bengal. Facing a flood of cases in West Bengal, health workers started looking for similar problems in Bangladesh, and found that millions of people all over the country were being poisoned by drinking arsenic-laced water. Arsenic contamination in Bangladesh was first identified in 1993 by the Department of Public Health Engineering of the government of Bangladesh in the tubewell water in the Chapai Nawabganj district in the north-western part of the country.<sup>15</sup>

The World Health Organization (WHO) guideline value (recommended limit) for arsenic in drinking water is 10 µg/L and the national standard in most countries, including Bangladesh, is 50 µg/L. With varying levels of contamination from region to region, the groundwater of sixty-one out of sixty-four districts in Bangladesh is contaminated with arsenic.<sup>16</sup> According to a study conducted by the British Geological Survey and the Department of Public Health Engineering (DPHE) of Bangladesh, arsenic concentrations in the country ranged from less than 0.25 µg/L to more than 1600 µg/L.<sup>17</sup> This study report estimates that out of the 1999 Bangladesh population of 125.5 million, up to 57 million are drinking water with an arsenic concentrations greater than the WHO guideline value and up to 35 million drinking water with concentrations in excess of the Bangladesh standard. The area containing the worst arsenic concentrations stretches across the south and east of Bangladesh. The capital city of Dhaka appears to be more or less safe from arsenic contamination (less than 0.5 µg/L arsenic).

**Figure 2.2: Number of People Drinking Arsenic Contaminated Water in Bangladesh**



### Sources of Arsenic: A Natural Origin?

It is now generally agreed that the arsenic contamination of groundwater in Bangladesh is of natural origin, deriving from the geological strata underlying Bangladesh.<sup>18</sup> It is also suggested that this arsenic is transported by rivers from the sedimentary rocks in the Himalayas.<sup>19</sup>

<sup>15</sup> S.M.A Muslim, "Arsenic Contamination of Groundwater in Bangladesh and Its Remedy," *The Daily Star* (Dhaka), January 14, 2002 (published in Bangla as a special feature on the occasion of the government-sponsored International Workshop on Arsenic Mitigation in Bangladesh).

<sup>16</sup> Ibid.

<sup>17</sup> D.G. Kinniburgh and P.L. Smedley, eds., *Arsenic Contamination of Groundwater in Bangladesh*, *British Geological Survey Report*, Volume 2 (Keyworth, Nottingham: British Geological Survey, 2001).

<sup>18</sup> Elizabeth M. Jones, *Arsenic 2000: An Overview of the Arsenic Issue in Bangladesh*, Draft Final Report (Dhaka: WaterAid Bangladesh, December 2000).

<sup>19</sup> Draft Development Strategy: National Water Management Plan (NWMP, 2000).



The arsenic is thought to be closely associated with iron oxides. Arsenic occurs in two oxidation states in water. In reduced (anaerobic) conditions, it is dominated by the reduced form: arsenite. In oxidizing conditions the oxidized form dominates: arsenate. The release mechanism of arsenic from the sediment is not yet clearly understood, but two major theories for the release of arsenic are put forward:

**Pyrite oxidation:** This associates the release of arsenic with oxidation due to draw-down of the water table, particularly by irrigation extraction. In response to the pumping of water, air or water with dissolved oxygen penetrates into the ground, leading to decomposition of sulphide minerals and release of arsenic.

**Oxyhydroxide reduction:** Arsenic naturally transported in the river systems of Bangladesh is adsorbed onto fine-grained iron or manganese oxyhydroxides. These were deposited in flood plains and buried in the sedimentary column. Due to the strong reducing conditions that developed in the sediments and groundwater of certain parts of Bangladesh, the arsenic continues to be released into groundwater.

The second theory is thought to be the more likely explanation. However, some other hypotheses like microbial activity and the effects of deposition via arsenic contaminated fertilizer have also been hypothesized.

Natural processes of groundwater flushing will eventually wash the arsenic away but this will take thousands or ten thousands of years. The flushing is particularly slow in the Bengal Basin in general because it is so large and flat.

The majority of tests to date have been carried out on shallow tubewells used for drinking water. A significant number of tests have also been carried out on deep tubewells down to 300 meters or more, used for drinking water, and other wells (also referred to as deep tubewells) down to 100 meters used for agriculture. The tests show that at depths below 200 meters the incidence of contamination falls off and at 250 meters or more it is rare. In general, it appears that water drawn from depths greater than 250 meters is, and will remain, arsenic-free provided that irrigation wells do not start using the same aquifer.<sup>20</sup>

However, according to Islam and Uddin (2002), the distribution of arsenic in the groundwater is related to the geology of the country rather than just the depth of the water table.<sup>21</sup> According to them, the division of the aquifer system from the geological point of view—like the Upper Holocene aquifer, Middle Holocene aquifer, Upper Pleistocene-Early Holocene aquifer, Plio-Pleistocene aquifer, and older aquifers—is more logical when applied to the depth of the tubewell pumping system as is customarily adopted in Bangladesh. They conclude that most of the arsenic-contaminated tubewells are drawing water from the Middle and Upper Holocene sediments.

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<sup>20</sup> Ibid.

<sup>21</sup> M. Nazrul Islam and Md. Nehal Uddin, "Hydrology and Arsenic Contamination in Bangladesh," in *Arsenic Mitigation in Bangladesh*, eds. M. Feroze Ahmed and Chowdhury Mufad Ahmed (Dhaka: Local Government Division, Ministry of Local Government Rural Development & Cooperatives, Government of the People's Republic of Bangladesh, 2002).



**PART THREE**  
**Drinking Death in Groundwater**

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### **Arsenic Contamination as a Major Health Hazard in Bangladesh**

Bangladesh is in midst of what some experts say could be the largest mass poisoning in history. While initially it was thought that only a few scattered areas of the country have this problem, now it has been confirmed that the problem is much more widespread: as cited earlier, sixty-one out of sixty-four districts of the country are reported to be affected by groundwater arsenic contamination. It has been officially recognized that there are at least 35 million people who are living with the threat of possible arsenic contamination, if we consider the Bangladesh standard for arsenic in groundwater (50 µg/L). On the basis of the World Health Organization (WHO) guidelines (10 µg/L), however, the situation is even worse: about 57 million people are exposed to the risk of arsenic pollution. Arsenic is entering into the bodies of millions of people sip by sip as they drink the water from a vast system of tubewells. Since it takes two to fourteen years for arsenic to have visible effect on the human body, a lethal environmental health disaster is unfolding slowly in Bangladesh.

### **Toxic Effects of Arsenic on Health**

As a semi-metallic naturally occurring chemical, arsenic is all around us in the environment and we are all exposed to small doses on a regular basis. It is difficult to detect arsenic because at typical contamination levels it is odorless and flavorless, meaning people have little idea when it is around.<sup>22</sup>

Arsenic has long been recognized as a toxin and carcinogen. This ubiquitous element can kill humans quickly if consumed in large amounts. Poisoning may result from a single large dose (acute poisoning) or from repeated small doses (chronic poisoning). Symptoms of acute poisoning from swallowing arsenic include nausea, vomiting, burning of the throat, and severe abdominal pains. Circulatory collapse may occur and be followed by death within a few hours.<sup>23</sup>

Chronic exposure to arsenic can occur through various sources, both natural (e.g., weathering reactions and volcanic emissions) and man-made (e.g., mining related activities). Of the various sources of arsenic in the environment, drinking water probably poses the greatest threat to human life.<sup>24</sup> The clinical manifestation due to chronic arsenic toxicity usually develops only after a prolonged latency period of several years. The most common effects of arsenic include gradual loss of strength, diarrhea or constipation, pigmentation and scaling of the skin, nervous system manifestations marked by paralysis and confusion, degeneration of faulty tissue, anemia, and the development of characteristic streaks across fingernails. A number of internal cancers (lung, bladder, liver, prostate, and kidney cancer) are also believed to be linked with chronic arsenic toxicity.

It is assumed that it may take two to twenty years for a person exposed to arsenic to develop the symptoms of *arsenicosis*, the name by which the disease is known.<sup>25</sup> The period differs from patient to patient depending on the amount of arsenic ingested, nutritional status of the person, immunity level of the individual, and the total time period of arsenic ingestion.<sup>26</sup> While the early symptoms of arsenicosis can be treated, many of the more advanced and most serious clinical symptoms are incurable.

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<sup>22</sup> BBC News, "Arsenic Poisoning," September 27, 1999, [http://news.bbc.co.uk/1/hi/health/medical\\_notes/459078.stm](http://news.bbc.co.uk/1/hi/health/medical_notes/459078.stm).

<sup>23</sup> Ranjit Kumar Dey, "Arsenic Health Problem," in *Arsenic Mitigation in Bangladesh*, eds. M. Feroze Ahmed and Chowdhury Mufad Ahmed (Dhaka: Local Government Division, Ministry of Local Government Rural Development & Cooperatives, Government of the People's Republic of Bangladesh, 2002).

<sup>24</sup> "Water Quality Fact Sheet: Arsenic" (WaterAid and the British Geological Survey, 2000).

<sup>25</sup> *The International Workshop on Arsenic Mitigation in Bangladesh*, January 2002, has defined arsenicosis as "a chronic condition due to prolonged exposure of arsenic above safe level usually manifested by characteristic skin lesions with or without involvement of internal organs and malignancies."

<sup>26</sup> Rahman Quamruzzaman and Asad, "Effects of Arsenic on Health," in *The Report of the Specialized Course on Arsenic Contamination in Bangladesh* (Dhaka: International Training Network Centre [ITN] Bangladesh, May 18–23, 2002).

The poisoning that is taking place in Bangladesh through arsenic-contaminated groundwater is chronic in nature. In most cases, the victims initially do not have any complaint or symptoms until they are detected through a screening survey. The symptoms of arsenicosis are very difficult to differentiate from other clinical conditions. The present practice in diagnosing arsenicosis cases is by examination for external manifestation on the skin, called melanosis keratosis, in combination with a history of consuming arsenic-contaminated water.

### Social Costs of Arsenic Contamination

While addressing the problem of arsenic contamination, emphasis is being put on the identification, mitigation, and supply of safe drinking water. Arsenic is not only a physical but also a social phenomenon; the social fallout of arsenicosis is enormous. The arsenic hazard has a strong social dimension, affecting issues such as relationships within the family and the village, as well as the mental health of the sick.<sup>27</sup>

Dr. Mahbuba Nasreen from the Department of Sociology, University of Dhaka, observed the social costs of arsenic contamination in the following forms: social instability, superstition, ostracism, marital problems, discrimination against women, increased poverty, diminished working ability, and death.<sup>28</sup>

**Social Instability:** Lack of proper knowledge about arsenic contamination and unavailability of arsenic-safe drinking water as well as proper treatment are creating extreme instability in the social life of the people in the arsenic-prone areas of Bangladesh. Moreover, social conflict over contaminated water contributes to destruction of social harmony and network relationships.

**Superstition:** Superstitions and prejudices are constructed surrounding arsenic patients. For example, in the north-eastern district of Kushtia, arsenic is considered as a “curse of Allah” or the work of evil spirits.<sup>29</sup> People stay away from arsenic victims, neglect them, or become scared of them because of these superstitions.

**Ostracism:** Arsenic patients are often identified by the society as patients of leprosy and as a result they remain ostracized, at either the household or the village level. Children of arsenic patients are not allowed to attend social or religious functions. The patients as well as their close relatives are not allowed to use public tubewells and village ponds. Often family members, like husbands or wives, abandon the arsenicosis victims.

The problem is more serious in the case of children.<sup>30</sup> The entry of arsenic affected children into schools becomes restricted. Some may be denied the opportunity to go to school. They also are subject to social ostracism by their friends and classmates.

**Diminished working ability:** Arsenic is a silent killer. The black spots on a victim’s body slowly become nodules and even grow if the victim remains exposed to arsenic contamination. Limbs and internal organs like the liver, kidney, and lungs may be affected. Gangrene cripples the victim and makes him or her unable to do hard labor. Arsenic is carcinogenic.

**Marriage related problems:** Arsenic has an adverse impact on marital relationships. People are reluctant to develop marital relationships with families whose members suffer from arsenicosis. This has caused serious anxiety for parents of unmarried adult children. Many women are divorced or abandoned by their husbands due to arsenicosis.

**Increased poverty:** Those in poverty are the main victims of arsenic contamination as they are compelled to drink contaminated tubewell water. Researchers believe that the severity of arsenicosis is very much related to nutritional deficiency. Malnutrition makes them easy victims. Due to poverty, victims are deprived of proper treatment. When seeking treatment, the costs become a burden to them.

<sup>27</sup> World Health Organization, *Towards an Assessment of the Socioeconomic Impact of Arsenic Poisoning in Bangladesh* (Geneva: WHO, 2000).

<sup>28</sup> Mahbuba Nasreen, “Social Impact of Arsenicosis,” in *Arsenic Contamination in Bangladesh* (Dhaka: ITN Bangladesh, 2002).

<sup>29</sup> *The Bangladesh Observer* (Dhaka), September 11, 2000.

<sup>30</sup> Javed Yousuf Bidyut, Jinat Nahar Jitu, Ranajit Das, Dr. Bashir Ahmed, Tarik Hassan Protik, and Ariful Islam, “Social Impacts of Arsenicosis” (paper presented at the 3<sup>rd</sup> International Arsenic Conference organized by Dhaka Community Hospital, Dhaka, Bangladesh, May 13–14, 2000).

As arsenicosis decreases the victim's ability to work, he or she often suffers from a reduced income. Due to ostracism, arsenic patients lose their jobs. Thus, arsenic negatively contributes to the poverty situation in Bangladesh.

**Gender implications of arsenic contamination:** In Bangladesh women perform the majority of the household work, but their work remains relatively invisible and unrecognized in society. Among many other tasks, collecting and carrying water for household use, particularly in the rural areas, is the responsibility of women and girls. Arsenic contamination in nearby drinking water often compels them to collect and carry water from a long distance, imposing an additional burden on them.

Because of socio-cultural restrictions, women often do not receive opportunities to obtain information from outside sources. Thus, they are not properly aware of the danger of arsenic. This makes arsenic mitigation activities difficult.

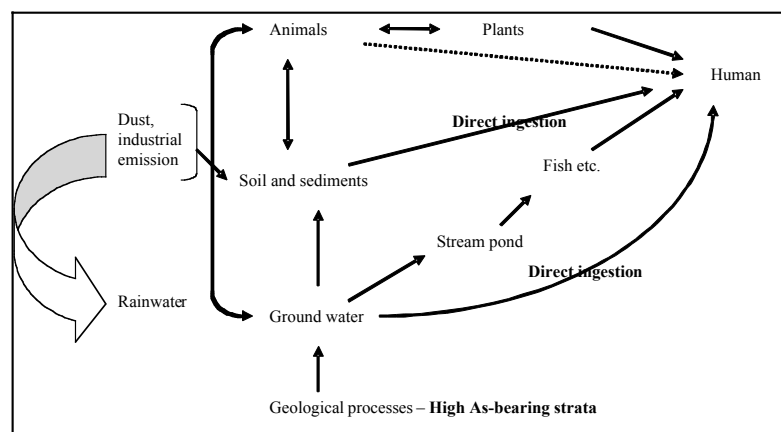
Women are frequent victims of ostracism due to arsenicosis. They are doubly vulnerable: from the disease itself and by being divorced, abandoned, or even forced out of the society. As gender discrimination exists in many forms in the patriarchal society of Bangladesh, women suffer more from these things than men.

### Arsenic in the Food Chain

By now, the dangers of drinking arsenic-contaminated water have been well recognized. Consequently, research and studies are focusing on ensuring safe drinking water, either through mitigation techniques or through finding alternative sources of arsenic-safe drinking water. However, these studies do not discuss all potential arsenic exposure pathways that are important to animal and human systems. Even if an arsenic-safe drinking water is ensured, contaminated groundwater will continue to be used for irrigation purposes. Its use creates a risk of soil accumulation by the toxic element and eventual human exposure to it through the food chain via plant uptake and animal consumption. Between thirty and forty percent of the net cultivable area of the country is under irrigation and more than sixty percent of irrigation needs are met from groundwater, either through deep tubewells or through shallow tubewells.

The observation that arsenic poisoning amongst the population is not consistent with the level of arsenic in water has raised questions on potential pathways of arsenic ingestion. This necessitates an in-depth study on the bio-magnification of arsenic toxicity through the food chain.

**Figure 3.1: Total Exposure of Human Beings to Arsenic in Nature**



Reproduced from: S.M. Imamul Huq and Naidu, Ravi, "Arsenic in Groundwater of Bangladesh: Contamination in the Food Chain," in *Arsenic Contamination in Bangladesh* (Dhaka: ITN Bangladesh 2002).

A recent study conducted by S. M. Imamul Huq of the Department of Soil, Water & Environment, Dhaka University, and Ravi Naidu of Commonwealth Scientific and Industrial Research Organisation (CSIRO), Land and Water, Australia, demonstrates that apart from direct ingestion through drinking water, the major possible pathways of arsenic contamination are Soil-Crop-Food, as well as cooking water.<sup>31</sup> The transfer could be schematized as Groundwater→Land→Crop→Human Beings. The study by Huq and Naidu analyzed water, soil, and vegetables/crops growing on arsenic contaminated lands in fourteen districts (out of sixty-four in the country). Fish, cooked food, and grasses were also analyzed. The study concluded that there is a possibility of arsenic ingestion through consumption of different food materials.

Research is continuing into the impacts that irrigation with arsenic-contaminated water might have on food safety. According to the National Water Management Plan (December 2001), no firm conclusion can be drawn as yet. If it is shown to be unsafe, the implications will depend on whether the health hazards are applicable to some or all crops, and whether treatment is a viable option. However, if there were a need to ban irrigation from groundwater in these areas, the impacts would be moderated by the fact that most shallow tubewell irrigation is not in areas of high arsenic contamination.

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<sup>31</sup> S.M. Imamul Huq and Ravi Naidu, "Arsenic in Groundwater of Bangladesh: Contamination in the Food Chain," in *Arsenic Contamination in Bangladesh* (Dhaka: ITN Bangladesh, 2002).

## PART FOUR

### Arsenic in Groundwater Across the World

The extent of the arsenic problem worldwide is as yet unknown. Before arsenic was identified as the unambiguous cause of wide-scale health problems in Bangladesh, such occurrences were considered relatively isolated. However, since the 1990s, efforts by governments, external support agencies, and academic institutions to identify other potential contamination areas have dramatically increased.<sup>32</sup> Although it is far too early to outline definitively the extent of the problem globally, it is clear that there are many countries in the world where arsenic in drinking water has been detected at concentrations greater than the WHO guideline value (10 µg/L) or the prevailing national standard.<sup>33</sup>

**Figure 4.1: Documented Cases of Arsenic Problems in Groundwater Related to Natural Contamination**



Source: British Geological Survey, 2001, <http://www.bgs.ac.uk/>.

Distinctive groundwater arsenic problems result both from natural sources (in reducing as well as in oxidizing groundwater conditions) and from anthropogenic activities (mining, for example). Arsenic associated with geothermal waters has also been reported in several countries. Table 4.1 below summarizes the state of arsenic contamination in different countries around the globe.<sup>34</sup>

<sup>32</sup> World Health Organization, United Nations Synthesis Report on Arsenic in Drinking Water, 2003, [http://www.who.int/water\\_sanitation\\_health/dwq/arsenic3/en/](http://www.who.int/water_sanitation_health/dwq/arsenic3/en/).

<sup>33</sup> World Health Organization, *Arsenic in Drinking Water*, WHO Fact Sheet No. 210 (Geneva: WHO, revised May 2001).

<sup>34</sup> This portion has been collated from the following sources: World Health Organization, United Nations Synthesis Report on Arsenic in Drinking Water, 2003, [http://www.who.int/water\\_sanitation\\_health/dwq/arsenic3/en/](http://www.who.int/water_sanitation_health/dwq/arsenic3/en/); D.G. Kinniburgh and P.L. Smedley, eds., *Arsenic Contamination of Groundwater in Bangladesh*, *British Geological Survey Report*, Volume 2 (Keyworth, Nottingham: British Geological Survey, 2001); Sirajul Islam, ed., *Banglapedia: National Encyclopedia of Bangladesh* (Asiatic Society of Bangladesh, March 2003); Md. Harun-ur-Rashid and Md. Abdul Karim Mridha, "Arsenic

**Table 4.1: Arsenic Contamination across the Globe**

Country	Origin of arsenic	First identified	Affected region	Range of contamination	Population exposed
Argentina	Natural, due to the soil composition polluting the shallow well waters. Also high content in some river waters.	Beginning of the 19 <sup>th</sup> century	The Chaco-Pampean Plain of Central Argentina, covering around one million sq. km.	Groundwater arsenic concentration in some places ranges from 100 to 2000 µg/L	200,000
Bangladesh	Natural origin, deriving from the geological strata underlying Bangladesh	1993	61 out of 64 districts	Less than 0.25 µg/L to more than 1600 µg/L	Up to 57 million are drinking water with an arsenic concentrations greater than the WHO guideline value, and up to 35 million drinking water with concentrations in excess of the Bangladesh standard
Chile	Associated with quaternary volcanism in the sparsely populated and arid Central Andean Codilleras	1962	Arica Province in north Chile	Not available	400,000 over an area of 125,000 sq. km.
China	Natural, in reducing environment	First identified in Xinjiang Province in early 1980s	Inner Mongolia Shaanxi and Xinjiang Provinces	90% of the wells tested had arsenic at level higher than 50 µg/L (highest concentration detected was 2400 µg/L)	600,000 in China and 1.1 million in Inner Mongolia
Ghana	Effects of mining activities and possibly some arsenopyrite oxidation	Not available	Obuasi	Some shallow wells and streams contain low to high concentration	100,000

Contamination of Groundwater in Bangladesh” (paper presented at the 24<sup>th</sup> WEDC Conference, Islamabad, Pakistan, 1998); World Health Organization, *Arsenic in Drinking Water*, WHO Fact Sheet No. 210 (Geneva: WHO, revised May 2001).



Hungary and Romania	Natural	Not available	Southern part of the Great Hungarian Plain and parts of neighboring Romania	2 to 176 $\mu\text{g/L}$	400,000
India	Geological origin, analogous to the problem in Bangladesh	Resultant health effects were first identified in late 1980s	West Bengal (8 out of 17 districts) Also suspected occurrence in Bihar, Gangetic and Brahmaputra plains	Not available	Over 5 million. Estimated 300,000 people are suffering from various stages of arsenicosis
Mexico	Natural. volcanic sediment type aquifer having oxidizing, neutral to high pH groundwater condition	Not available	Lagunera Region of north central Mexico. Affected area expands up to 32,000 sq. km. Northern region is also believed to have arsenic contamination.	1 to 500 $\mu\text{g/L}$ (average 100 $\mu\text{g/L}$ )	400,000
Nepal	Not known, but believed to be natural	Late 1990s. When the gravity of the problem in India and Bangladesh was identified, water experts in Nepal decided it was time to look into the quality of water supply there.	20 Terai districts in the plains of Nepal	Not available	550,000 people (2.4% of population) exposed to arsenic exceeding 50 $\mu\text{g/L}$ and 3.19 million (13.6% of population) exposed to arsenic exceeding 10 $\mu\text{g/L}$

Taiwan	Natural. The contaminated aquifer is sediment type with shale. Contamination is analogous to the one of Bangladesh and West Bengal.	1968	Southwest and north coastal zones	In some areas, concentration of arsenic is as high as 1800 µg/L	200,000
Thailand	Oxidation of arsenopyrite from former tin mining.	1996	Southeast Asian Tin Belt, in and close to Ron Phibun town. Affected area is around 100 sq. km.	1 to 500 µg/L	Not available
The United States	Natural occurrences in groundwater (in both reducing and oxidizing environments). There are also areas where arsenic comes from geothermal sources and mining related activities	Not available	Southwestern states of Nevada, California and Arizona. Arsenic associated with geothermal sources occurs in certain areas in California, Nevada and Los Angeles. Some areas in Alaska, California, Nevada, and South Dakota have arsenic arising from mining activities.	Varied	The Environmental Protection Agency of the United States has estimated that some 13 million are exposed to arsenic in drinking water at 10 µg/L
Vietnam	Due to toxic condition of the aquifer	Very recently	Mekong and Red River delta region, including Hanoi.	On an average, 430 µg/L in most affected district.	Not available

From the above observations, it is clear that arsenic contamination of groundwater exists in many parts of the world, but Bangladesh is the country where the problem is most acute, with the lives of millions of people at stake.

## PART FIVE

### Facing the Challenge of Arsenic Contamination

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The development of a mitigation strategy for the arsenic contamination of groundwater in Bangladesh should consider all relevant factors and variables, but the strategy must focus clearly on water. In the case of arsenic in drinking water as a major health hazard for the people of Bangladesh, water is the principal cause and water management is the only cure.<sup>35</sup> Although mitigation options are guided by similar considerations for both the industrialized and the developing countries, the latter face additional constraints on financing as well as on technical and administrative capacity.

There are no available medical options that can either block or cure arsenicosis. Medical interventions are limited to alleviating the effects of symptoms and treating diseases, such as cancer, that can ultimately result from arsenic exposure. The only way to prevent arsenicosis in the first place is to ensure that arsenic ingestion does not occur. The first and most important step in the treatment of arsenicosis, when it does occur, is also to eliminate or reduce arsenic exposure. For Bangladesh, where water is the principal source of arsenic, efforts to reduce arsenic intake should concentrate on the provision of arsenic-free water.

#### Identification of the Scale and Nature of the Problem: Screening the Tubewells

The first step in addressing the arsenic problem in Bangladesh is to identify the scale and nature of the problem as well as to screen for tubewells that are affected. In areas where groundwater arsenic problems may be suspected but data are lacking, a broad scale randomized survey of selected tubewells is required to identify the scale of the potential problem. The arsenic map of Bangladesh, developed by a joint BGS-DPHE survey, shows that there are clear regional differences in the extent of contamination. As a consequence of the high degree of short-range spatial variability in arsenic concentration, all wells in the “at risk” aquifers need to be tested if they are used for drinking water. This is a huge task and presents severe technical, institutional, and social challenges. Given the scale of the problem, such testing will be feasible only by using field test kits.

Testing of arsenic in water identifies which tubewells are unsafe for drinking and cooking, and at the same time, also identifies which tubewells are safe. This is the simple and most immediately achievable option for the provision of arsenic-free water; communities can share the water of tubewells that are currently low or free of arsenic. At present, the tested tubewells are being painted green and red, indicating safe and unsafe respectively. There is also the possibility of selective use of the contaminated water, for washing for example. However, since arsenic contamination in Bangladesh is a widespread phenomenon, the concentration of arsenic in selected wells should be checked on a regular basis, because previously safe tubewells could gradually be found to contain increased levels of arsenic. This has happened in Mexico, and was also reported in West Bengal, where deep wells, originally arsenic-free, over time started to draw from contaminated layers.

#### Increasing Awareness

The problem of arsenic in Bangladesh is a new phenomenon and experts have only recently studied the causes, nature, and prevention of the problem. Until recently, awareness of arsenic was very low. The general population was largely unaware of the danger of drinking arsenic-contaminated water. A 1998 National Media Survey found that only 14 percent of households knew of the arsenic poisoning of groundwater. Since arsenic in water is odorless, colorless, and nearly tasteless even at dangerous levels, people do not realize that they are drinking poison in their water. The absence of appropriate safe sources of water has made the situation even more complicated.

It is now urgent to redefine the concept of safe water so that people are able to understand that consuming arsenic-contaminated water has serious health and economic implications, and to make people aware about the

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<sup>35</sup> World Health Organization, United Nations Synthesis Report on Arsenic in Drinking Water, 2003, [http://www.who.int/water\\_sanitation\\_health/dwq/arsenic3/en/](http://www.who.int/water_sanitation_health/dwq/arsenic3/en/).

desirability of switching to a safe water supply. This must be an integral part of arsenic mitigation activities in Bangladesh.

Media can play a pivotal role in general awareness building. Newspapers, radio, and television are working in this regard, but much is yet to be done. Considering the fact that 74 percent of the people of Bangladesh live in rural areas, and that most of them do not have access to the aforesaid media, other forms of information tools, like instructional films, leaflets, posters, etc., should also be used for awareness building. Information materials on arsenic should also inform the people about, among other things, arsenic contamination, arsenicosis, available safe water options, the need to switch to safe sources of water, and community sharing of safe water.

### Who Is Doing What in Arsenic Mitigation

The discovery of arsenic contamination in Bangladesh has resulted in an unprecedented response from the government of Bangladesh as well as from non-governmental organizations (NGOs) and development partners. A report from WaterAid Bangladesh (2000) summarizes some thirty-five large-scale projects for arsenic mitigation in Bangladesh.<sup>1</sup> These projects have addressed specific issues relating to the arsenic problem. They could not find a single “master” technological solution to the problem, but a number of mitigation options have been developed to face the challenge of arsenic pollution.

Although arsenic in tubewell water of Bangladesh was first identified in 1993, the issue became more public following a seminar at the School of Environmental Sciences (SOES), Jadavpur University, Calcutta in 1995.<sup>2</sup> Since then, the government of Bangladesh became active in addressing the problem, and donors started pouring funds into projects to find a solution. NGOs and research organizations started conducting arsenic-related studies.

The government organizations working in the arsenic field include the Directorate of Health, Department of Public Health Engineering, National Institute for Preventive and Social Medicine (NIPSOM), Bangladesh Water Development Board (BWDB), Geological Survey of Bangladesh (GSB), and the Bangladesh Atomic Energy Commission.<sup>3</sup> Among them, DPHE has a number of arsenic activities at various levels of implementation and is working with a wide variety of development organizations.<sup>4</sup> DPHE has conducted, in collaboration with the British Geological Survey (BGS) and Mott MackDonald Limited, the most comprehensive and systematic survey throughout Bangladesh on arsenic. NIPSOM has so far done considerable work both in terms of identifying arsenic-affected patients and analyzing groundwater.<sup>5</sup> The University of Dhaka, University of Rajshahi, and the Bangladesh University of Engineering and Technology (BUET) are conducting studies on arsenic.

NGOs are playing a pivotal role in addressing the arsenic menace. Dhaka Community Hospital, BRAC, Grameen Bank, NGO Forum, and BCAS are among the most active NGOs in this field.

Both the government and NGOs receive financial and technical support from international organizations and other development partners like the United Nations Children’s Fund (UNICEF), United Nations Development Program (UNDP), World Bank, World Health Organization (WHO), Department for International Development (DFID) of the UK, and the Swiss Agency for Development and Cooperation (SDC).

All these initiatives are making significant contributions to the study of arsenic contamination in general, but lack of collaboration among different organizations is working as a barrier to those addressing the catastrophe.<sup>6</sup>

<sup>1</sup> Elizabeth M. Jones, *Arsenic 2000: An Overview of the Arsenic Issue in Bangladesh*, Draft Final Report (Dhaka: WaterAid Bangladesh, December 2000).

<sup>2</sup> Sirajul Islam, ed., *Banglapedia: National Encyclopedia of Bangladesh* (Asiatic Society of Bangladesh, March 2003).

<sup>3</sup> Ibid.

<sup>4</sup> Jones, *Arsenic 2000*.

<sup>5</sup> Islam, *Banglapedia*.

<sup>6</sup> Mahbuba Nasreen, “Social Impacts of Arsenicosis,” in *Arsenic Contamination in Bangladesh* (ITN Bangladesh, 2002).

## Healthcare Options

With some 35 to 57 million people drinking arsenic-contaminated water, Bangladesh is experiencing a serious health hazard. The first step in providing healthcare options for people suffering from arsenic is identifying them. But it is not an easy task; arsenic is a slow poison and symptoms of arsenicosis develop only after a prolonged consumption of arsenic-contaminated water. The exact number of people suffering from arsenicosis in Bangladesh is still not known. As of 2002, over 10,000 cases of arsenicosis have been identified, but it is not clear whether we are looking at the tip of the iceberg. The screening that has been done by the Bangladesh Arsenic Mitigation Water Supply Project, a joint World Bank-Government of Bangladesh project, shows figures of 1.1 cases of arsenicosis per thousand people. Extensive surveys and research projects need to be conducted on an urgent basis to develop a reliable data set on the problem. Immediate efforts should be focused on those communities with higher levels of arsenic concentration in their domestic water supplies.

So far there is no particular medical treatment that can either prevent or cure arsenicosis; available medical interventions can only treat the symptoms of the disease. The best preventative is to drink arsenic-safe water. The arsenicosis patient should immediately stop the consumption of arsenic-contaminated water. Then emphasis should be put on the provision of a diet high in protein and vitamins. Some research suggests that a better diet, especially when supplemented with Vitamin A, Vitamin C, Vitamin E, and protein, can help the body to fight arsenic. Skin lesions that develop due to exposure to arsenic can be treated with medicated lotions.

With the problem of arsenicosis being new to Bangladesh, many doctors and health professionals are not yet aware of it, nor they are trained to recognize the symptoms. The government of Bangladesh, along with UNICEF and some other organizations, is working on providing appropriate training to the health professionals in this regard.

## Mitigation of Arsenic: Alternative Sources of Safe Drinking Water

As has been previously mentioned, the most immediately achievable option for safe drinking water is identifying the tubewells with low levels of arsenic contamination and then sharing their water within the community. However, it is possible that in severely contaminated localities there will be no tubewell with safe levels of arsenic. Moreover, the apparently safe tubewells may later produce water with a concentration of arsenic beyond the permissible limit. Therefore, it is important to develop some feasible and cost-effective means, based on local technology, for an effective arsenic mitigation program in Bangladesh.

In assessing the best alternative water options and arsenic removal technologies the following basic criteria should be evaluated:

- Water quality (e.g. does the system consistently provide bacteriologically and chemically safe water?)
- Water quantity (e.g. flow rate, access to water at peak times)
- Affordability (capital, operation, and maintenance)
- Reliability
- Life expectancy (e.g. how does one know when to change filter media?)
- Convenience (e.g. time and effort involved)
- Time considerations
- Gender issues (e.g. ergonomically appropriate, division of power)
- Environmental risks (e.g. sludge disposal, excess water/drainage issues)
- Operational safety (e.g. potential for accidental misuse, physical and chemical safety, robustness)
- Risk substitution (e.g. introduction of bacteriological contamination)
- Logistical sustainability of system (e.g. reagents are locally available, life-time of system, market base, involvement of private sector)
- Necessary operation and maintenance training

- Information, Education, and Communication.<sup>36</sup>

The scale of the arsenic problem in Bangladesh is clearly very large and complex, as is now widely acknowledged, and therefore it is difficult to find a single “master” technological solution to the problem. A number of solutions to the arsenic problems in vulnerable aquifers, as is the case in Bangladesh, have been suggested for different situations. The only clear conclusion is that no single solution is appropriate for all problems. Therefore, the mitigation measures outlined below should not be seen as a list from which the most preferable should be selected, but the basis for development of a portfolio of alternatives.

Apart from using the water from safe tubewells, the options available for safe drinking water supply in arsenic affected areas can be brought into two major categories:

- 1) Treatment of arsenic contaminated water: there are several treatment methods available to reduce arsenic concentration to an acceptable level for drinking.
- 2) Alternative arsenic-safe water sources: Groundwater from deep aquifers and dug wells, surface water, and rainwater can be potential sources of water supply to avoid arsenic ingestion via shallow tubewell water.

### ***Treatment of Arsenic Contaminated Water***

There are several methods available for removal of arsenic from contaminated water, both at the community and household level. These options are needed to make use of the huge number of tubewells likely to be declared abandoned for producing water with high levels of arsenic concentration. The most commonly used methods of treatment of high-arsenic water are by addition of coagulants such as alum and potassium permanganate. Table 5.1 shows a comparison of the main technologies for arsenic removal.

These methods are basically for use in large conventional treatment plants, but some of them can be reduced in scale and conveniently be applied at the household level. During the last few years, many small-scale arsenic removal technologies have been developed, field-tested, and used under arsenicosis prevention and mitigation research programs in Bangladesh and India.

**Advantages and disadvantages:** The failure of concerted efforts to provide community water supplies for all is what led to the massive growth in private hand pump tubewells as a source of drinking water in the first place. The fact that rural people have grown used to drinking tubewell water is one of the principal reasons to consider arsenic removal from tubewell water as a suitable option for water supply. However, it is also said that community-level arsenic removal is preferable to household-level options. The question of viability of household arsenic removal units is associated with persuading millions of households to use those units and ensuring that they are used correctly, and is negatively juxtaposed with the advantages of centralized operation and maintenance. The household arsenic treatment method is regarded as an alternative for the transitional period until a “permanent” solution is found. Yet, considering the financial constraints of large-scale arsenic removal plant, in many arsenic affected areas, household arsenic removal units may be the only option in the absence of an alternative safe source of water supply.

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<sup>36</sup> Elizabeth M. Jones, *Arsenic 2000: An Overview of the Arsenic Issue in Bangladesh*, Draft Final Report (Dhaka: WaterAid Bangladesh, December 2000).

**Table 5.1: Technologies for Arsenic Removal**

Technologies		Advantages	Disadvantages
<u>Oxidation/ Precipitation:</u> Atmospheric oxygen, hypochloride, or permanganate is added to the water to oxidize arsenite to arsenate and thereby facilitate its removal.	<ul style="list-style-type: none"> <li>• Air Oxidation</li> <li>• Chemical Oxidation</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively simple and low-cost process</li> <li>• Chemical oxidation is a rapid process</li> <li>• Oxidizes other impurities and kills microbes</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively slow process (air oxidation)</li> <li>• It removes only a part of the arsenic</li> </ul>
<u>Coagulation/ Co-precipitation:</u> Coagulants form flocs that bind arsenic and are then filtered out.	<ul style="list-style-type: none"> <li>• Alum Coagulation</li> <li>• Iron Coagulation</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively low capital cost</li> <li>• Relatively simple operation</li> <li>• Common chemicals available</li> </ul>	<ul style="list-style-type: none"> <li>• Produces toxic sludge</li> <li>• Low removal of arsenic</li> <li>• Preoxidation is required</li> <li>• Removal efficiencies may be inadequate to meet strict standards</li> </ul>
<u>Sorption Techniques:</u> Arsenic is adsorbed onto surface of media.	<ul style="list-style-type: none"> <li>• Activated Alumina</li> <li>• Iron Coated Sand</li> <li>• Ion Exchange Resin</li> <li>• Other Sorbents</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively well-known and commercially available</li> <li>• Well-defined technique</li> <li>• Plenty of possibilities and scope of development</li> </ul>	<ul style="list-style-type: none"> <li>• Produces arsenic-rich liquid and solid waste</li> <li>• Replacement/ regeneration is required</li> <li>• High-tech operation and maintenance</li> <li>• Relatively high cost</li> </ul>
<u>Membrane Techniques:</u> Selectively permeable membranes remove arsenic by filtration.	<ul style="list-style-type: none"> <li>• Nanofiltration</li> <li>• Reverse Osmosis</li> <li>• Electrodialysis</li> </ul>	<ul style="list-style-type: none"> <li>• Well-defined and high removal efficiency</li> <li>• Toxic solid wastes produced</li> <li>• Capable of removal of other contaminants</li> </ul>	<ul style="list-style-type: none"> <li>• High capital and running costs</li> <li>• High-tech operation and maintenance</li> <li>• Arsenic-rich rejected water is produced</li> </ul>

Sources: This table is a modified reproduction of the table comparing different arsenic removal processes given by Dr. M. Feroze Ahmed in "Treatment of Arsenic Contaminated Water" (a theme paper presented during the International Workshop on Arsenic Mitigation in Bangladesh, Dhaka, January 14–16, 2002). Information is also collected from Elizabeth M. Jones, *Arsenic 2000: An Overview of the Arsenic Issue in Bangladesh*, Draft Final Report (Dhaka: WaterAid Bangladesh, December 2000).

### ***Alternative Tubewell Installation***

In Bangladesh, there are clear regional differences in the extent of arsenic contamination, and these differences are dictated to a considerable degree by the underlying geology. This high degree of short-range spatial variability in arsenic concentrations offers some potential for alternative tubewell siting. The aquifers at a depth greater than 150 meters in Bangladesh, as well as in West Bengal, India, have been found to be relatively free from arsenic contamination. A hydrology study conducted by the British Geological Survey (BGS) and the Department of Public Health Engineering (DPHE) of Bangladesh has shown that only about one percent of deep wells having depth greater than 150 meters are contaminated with arsenic higher than 50 µg/L (the Bangladesh standard of permissible limit of arsenic in drinking water) and five percent of tubewells have arsenic content above 10 µg/L (the WHO guideline value). In some places, such deep tubewells have been developed for safe drinking water supply. Thus, sinking of deep tubewells in arsenic affected areas can provide safe drinking

water; of course any new tubewell sunk now must be tested for arsenic before use. They should be monitored on a regular basis, too.

**Limitations:** Lateral and depth variations in arsenic concentration are not universally predictable in different aquifers. Some of the deep tubewells installed in the arsenic problem regions have been found to produce water with increasing arsenic content. Therefore, the occurrence of low arsenic groundwater in parts of Bangladesh and West Bengal cannot be used as a rule of thumb in other countries. Moreover, the provision of deep tubewells is an expensive process that involves significant extra cost. The replacement of existing shallow tubewells by deeper tubewells, too, involves huge cost. Finally, deep tubewells cannot be drilled in all areas; in some parts of Bangladesh, rocky layers make drilling impossible.

### ***Hand-Dug Wells***

Shallow open hand-dug wells, one of the oldest methods of groundwater withdrawal, have often been found to contain low levels of arsenic concentration in reducing (anaerobic) aquifers. The arsenic concentrations in dug wells are usually low at 10 µg/L or even less, normally complying with the WHO guideline value and invariably with the 50 µg/L Bangladesh standard. Tubewells only a few meters deeper in the same area have much higher concentration of arsenic. Also, the concentration of other dissolved minerals like iron is low in dug well water. It is still not fully known why the arsenic concentration is low in dug well water, but it is probably due to the maintenance of aerobic conditions in the open well that allows oxidation of the water and also to regular flushing of the shallowest parts of the aquifer by inputs of recent rains.

Low arsenic concentrations have been observed in dug wells in Bangladesh as well as in West Bengal and Ghana. This type of traditional well may be constructed, where feasible, to provide arsenic-safe drinking water. It would be worth mentioning here that although tubewells have replaced traditional dug wells in most of the places in Bangladesh, about 1.3 million people in both urban and rural areas are still using dug wells for their everyday supply of drinking water.

**Limitations:** While dug well water is safe from arsenic contamination, it is very difficult to protect the open dug wells from bacteriological contamination, as they are more vulnerable to pollution from the surface, particularly through contaminated surface water. However, adequate protection against bacteriological contamination is not impossible: UNICEF (India) has developed a sanitary well system with a well cover, hand pump, and chlorination pot for this purpose. Dug wells with sanitary protection are being installed in many areas in Bangladesh.

Another problem for dug wells is that some areas of Bangladesh have a thick impermeable surface, where it is not possible to install dug wells. In some areas dug wells do not produce adequate water. The construction and withdrawal of water is difficult in areas having very low water tables as well as in areas with loose sand and silt. Finally, the yield of water from dug wells is quite limited and hence dewatering is likely to be the factor limiting the productivity of dug wells.

### ***Rainwater Harvesting***

Rainwater as a safe source of drinking water is in use in many developing countries around the world, particularly in coastal areas, island communities, and other areas where aquifers are saline. The rainwater harvesting technology, a very simple and low-cost one, involves collection of rainwater using either a sheet material rooftop and guttering or a plastic sheet, and then diverting the water to a storage tank. Once in the tank, rainwater can be stored safely without bacterial contamination for several months.

As a tropical country, Bangladesh receives heavy rainfall (1900 to 2900 mm average per year) during the rainy season. Rainwater harvesting is not a new method in this country in the coastal districts, particularly on the offshore islands. Rainwater harvesting for drinking purposes has been commonly practiced on a limited scale for a long time. In coastal regions with high salinity problems, about thirty-six percent of households use rainwater for drinking purposes during the rainy season.

In the present context of arsenic contamination, rainwater harvesting is being considered and tried as a major alternative option for water supply in the arsenic affected areas in Bangladesh. The quality of rainwater is comparatively good, and the system is suitable for scattered settlements. The system can be constructed using local materials and there is no energy cost to run the system. Moreover, it is very easy to maintain and the system can be located very close to the consumption points.



**Limitations:** The initial cost of the rainwater harvesting system might be too high for some families, and the poorer segment of the population may not have a roof suitable for rainwater collection. Moreover, the fact that the availability of water is limited by rainfall intensity and available rooftop area, and that mineral-free rainwater has a flat taste, might deter people from choosing this option. In some circumstances there is the possibility of chemical contamination of the collected water, particularly where air pollution is a major problem. Bird feces and intrusion of insects can also cause contamination in the water.

#### ***Treatment of the Surface Water: Pond Sand Filters***

Surface water is typically low in arsenic and therefore a potentially attractive drinking water source in arsenic-rich areas. But surface water from rivers, lakes, and ponds is frequently contaminated with human and animal fecal matter and other materials. It can cause severe health problems if not treated.

The construction of community-type slow sand filters, popularly known as pond sand filters, can offer the possibility of the development of a low-cost, surface water-based supply system. Developed in the early 1980s by UNICEF and the Department of Public Health Engineering (DPHE) to provide saline-free drinking water in the coastal areas of Bangladesh, these pond sand filters can remove bacteria from surface water by filtering it through a large tank filled with sand and gravel. The surface water comes from a pond, which is exclusively reserved for drinking. The pond sand filter is a low-cost technology with very high efficiency in removal of bacteria and turbidity. It has received preferences as an alternative source of arsenic-safe water for medium size communities in arsenic affected areas. As of June 2000, there were some 3,710 pond sand filters installed throughout Bangladesh.

**Limitations:** The operation and maintenance of this type of filter is difficult, and secondary contamination can take place due to lack of proper maintenance. Often it is difficult to find an appropriate pond in which to install this filter and heavily contaminated ponds are not suitable for such filters. Moreover, many ponds dry up in the dry season in some parts of the country. Finally, people complain of foul taste in pond water and many resort to using it for cooking only.

#### ***Piped Water Supply***

The most convenient water supply system, in terms of collection and use, is undoubtedly piped water supply. In Bangladesh, only piped water can replace the existing vast system of tubewell water supply. It is the most convenient because water can be delivered to the close proximity of the consumers, piped water is safe from external contamination of any kind, and better quality control is possible in such a system. The arsenic-free and bacteriological contamination-free water for such a piped supply can be collected from any source like deep tubewell, treated surface, or arsenic-contaminated (but properly treated) water, and from community dug wells. In West Bengal, for example, large-scale urban piped water supplies distributing treated river water are being installed in some arsenic-affected areas. In Bangladesh also, a few community level piped water supply systems are being tried.

**Limitations:** This is a very expensive system and not suitable immediately for many large, dispersed, and rural communities in Bangladesh. It requires huge initial cost and moreover, piped water supplies for all domestic supplies may be too expensive for low-income groups of people. It is also technically inconvenient because of the scattered settlement patterns of the rural population in Bangladesh. It can be feasible as a potential solution to the arsenic problem only for urban fringe areas and clustered rural settlements.



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**PART SIX**  
**Recommendations**

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**The Need for a Concerted Effort**

As has been previously mentioned, the discovery of arsenic in groundwater in Bangladesh prompted an unprecedented response from the government of Bangladesh, international aid agencies, NGOs, and other development partners. Consequently, a number of mitigation options have already been developed. But it is observed that there is a lack of coordination among different agencies that is hampering the efforts to address this crisis.

The government of Bangladesh should play the central role in this regard. It must have a concrete policy with separate but compatible short- and long-term programs to mitigate arsenic contamination. This will enable all concerned authorities to undertake a coordinated action plan to implement arsenic mitigation plans. The government should coordinate all stakeholder activities in the sector.

Finally, all efforts in combating the arsenic menace should be implemented through active involvement of the local community, local government institutions, and local administrations. Local government institutions should be given sufficient arsenic mitigation resources in recognition of their key role in ensuring provision of arsenic-safe water to the people.<sup>37</sup>

***Determine the Extent and Gravity of the Arsenic Crisis***

The high degree of spatial variability of arsenic contamination of groundwater in Bangladesh compels the country to undertake, as a programming priority, the mammoth task of field testing of wells to determine the level of arsenic. Without testing it is difficult to judge the real scale of the problem at the national level and thus it is difficult to design a rational program strategy.<sup>38</sup>

***Inform Affected People As Well As Other Concerned Authorities***

The arsenic mitigation strategy should integrate, as a crucial element, a comprehensive and participatory information program that will enable the people to understand the grave consequences of drinking arsenic contaminated water, to make them aware of the desirability of switching to safe water supply options, and to stress immediate actions that can be taken by affected communities. Clear, simple, and consistent information will help avoid confusion and panic within the affected communities.

***Prioritize Reductions in Arsenic Intake: Increase the Number of People with Access to Safe Water***

It is imperative to provide the affected communities, particularly where 70 percent or more of the tubewells are arsenic contaminated, with water at reduced levels of arsenic on an emergency basis. In order to curb occurrences of arsenicosis, the focus should be on providing water with low arsenic contamination even if the national standards are not met immediately.

***Provide Emergency Medical Advice and Treatment to the Affected People***

Villages with high levels of arsenic in water should be provided with proper medical care on an emergency basis. Health workers need to be trained on case detection. Moreover, for an effective and proper clinical diagnosis of arsenicosis cases, high quality laboratories for epidemiological and diagnostic investigation, as well as an International Center for Arsenic Mitigation, should be established in Bangladesh.<sup>39</sup>

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<sup>37</sup> *Recommendations of the International Workshop on Arsenic Mitigation in Bangladesh, January 2002*, in *Arsenic Mitigation in Bangladesh*, eds. M. Feroze Ahmed and Chowdhury Mufad Ahmed (Dhaka: Local Government Division, Ministry of Local Government Rural Development & Cooperatives, Government of the People's Republic of Bangladesh, 2002).

<sup>38</sup> World Health Organization, United Nations Synthesis Report on Arsenic in Drinking Water, 2003, [http://www.who.int/water\\_sanitation\\_health/dwq/arsenic3/en/](http://www.who.int/water_sanitation_health/dwq/arsenic3/en/).

<sup>39</sup> *Recommendations of the International Workshop on Arsenic Mitigation in Bangladesh, January 2002*.

***Conduct Food Chain Studies***

The human health significance of other sources of arsenic, such as those via the food chain, needs to be further explored, as do the relationships between diet/nutrition and the long-term effects of arsenic, and the dose-response and dose-effect relationships in drinking water.<sup>40</sup>

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<sup>40</sup> Jones, *Arsenic 2000*.

**PART SEVEN**  
**Concluding Remarks**

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Until recently, the problem of the chronic effects of drinking water with low concentrations of arsenic has not been given due attention. A large number of people in Bangladesh are exposed to the contamination of arsenic in drinking water at unsafe levels. The appalling results of arsenic contamination are only now being revealed in this country. The fact that almost half of the tubewells of Bangladesh were installed only in the last few years makes us believe that gradually more and more arsenicosis cases are likely to emerge in the coming years.

This makes water service and the availability of safe drinking water complicated and difficult. Removal of arsenic is expensive and technical. Alternative water sources are, therefore, required. But it becomes complex, especially in poverty-stricken rural and urban areas.

The cost and complexity of arsenic mitigation results in diverse health hazards, particularly in developing countries like Bangladesh, as funds have to be directed from other health-related and developmental programs. In such a situation, the most important thing is to ensure that people ingest as little arsenic from drinking water as possible.

Arsenic contamination does not occur in a regular, consistent pattern. It may be at various levels depending on the geographical and socio-economic environment of the locality. In the case of Bangladesh, a high degree of short-range spatial variability in the levels of arsenic has been observed. Therefore the mitigation of arsenic should be executed to suit the local conditions and requirements. It is important to remember that no program related to arsenic mitigation should be carried out in isolation. The local community should be fully involved in the planning and the development of the water supply system, and all concerned people should partake in the managerial and financial responsibilities. Raising awareness of the masses about the importance of safe drinking water through communication and education is a prerequisite in this regard.

The government has a definite role in combating the arsenic menace. It must plan properly, implement mitigation programs, and inform people of the danger that the arsenic in drinking water poses for human beings. The government must cooperate with academic as well as research institutes to assess the causes and impact of arsenic poisoning and take up remedial measures whenever and wherever necessary.

It is now apparent that groundwater must undergo analysis for arsenic before it is used for drinking and cooking purposes. Though it is still unknown what the global impact of arsenic contamination is, it is an obvious threat to public health and it should be mitigated. The arsenic problem in Bangladesh and elsewhere has decidedly pointed out that water quality should be surveyed and included in all water development and participation program. The presence of arsenic in drinking water has also indicated that more research work is necessary to deter the potential health effects emerging from other inorganic elements present in water resources.