Managing the Arsenic Disaster in Water Supply: Risk Measurement, Costs of Illness and Policy Choices for Bangladesh

M. ZAKIR HOSSAIN KHAN

Economic Research Group
Dhaka, Bangladesh

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Kathmandu, Nepal

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Comments should be sent to M. Zakir Hossain Khan, Economic Research Group
Dhaka, Bangladesh, Email: zhkhan@ti-bangladesh.org

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Abstract

Arsenic poisoning is a major public health concern in Bangladesh. This study uses primary data to examine health impacts and costs associated with arsenic contamination of groundwater. The study estimates that some 7 to 12 million person-days per year are lost as a result of arsenic exposure. In addition, individuals who are sick spend between 207 (US$ 3.5) million to 369 (US$ 6.25) million taka per year for medical help. The total cost of illness as a result of exposure to arsenic is Tk 557 (US$ 9) to Tk 994 (US$ 17) million per annum or on average nearly 0.6 percent of the annual income of affected individuals. If it is possible to provide arsenic-free (within safe limit) alternative technologies to reverse the impact of arsenic, the social gains to Bangladesh are considerable. The study also finds that the threat of *Melanosis*--the black spot disease—and *Keratosis*—roughness in palms and soles— is high when there is cumulative exposure and that this threat is not the same for all wealth classes. Richer households take mitigation measures to reduce the threat on their health. Richer households also seem to be more successful in avoiding the incidence of *conjunctivitis* due to *Arsenicosis*. Women on the other hand are more likely to be affected by inflammation of the respiratory tracts--a sign of long-term exposure without recourse to medical help.

Key Words: Arsenic, health impact, drinking water, mitigation, avertive technology, Bangladesh.

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1. Introduction

Bangladesh, along with Nepal and the state of West Bengal in India, is facing a major disaster in terms of the arsenic contamination in groundwater aquifers. Arsenic is a natural mineral that is present in the soil. The concentration above 50 parts per billion (ppb) or 0.5 micro-gram per litre (mg/l) in water is likely to create health risks. Unfortunately, as estimated by the Bangladesh Arsenic Mitigation Water Supply Project, nearly 30 percentof all tube wells in 258 *Upazilas* of Bangladesh have a higher arsenic content than the recommended safe limit.[1] For Bangladesh, this means that an estimated 27 percent to 60 percent of the population is at risk from arsenic exposure (Smith, Lingas and Rahman, 2000).

Historically, Bangladesh has been a forerunner in South Asia in terms of providing its population with access to safe drinking water. Death due to cholera was successfully contained in the seventies and eighties by replacing existing sources of drinking water with tube wells, a strategy that was vigorously pursued by the Government of Bangladesh and donors. However, since the discovery of arsenic in ground water in the nineties, Bangladesh has struggled once again with the problem of delivering safe water. The government has tried to inform people about the presence of arsenic in drinking water sources through a binary color coding system. A green-colored tube-well is a safe one for collecting drinking and cooking water while a red-colored one is not. Nonetheless, either due to limited alternative sources of water or for other reasons, many households continue to use water from the “unsafe” tube-wells.

Interventions to supply arsenic-free drinking water require varying investments at the community level as well as household actions to obtain safe water. Invariably, this means that households have to bear some portion of the costs of such investments. But, what are households willing to pay for arsenic-free water? In this paper, we try to address this question by estimating the costs households bear as a result of exposure to arsenic. Using a cost-of-illness approach, we assess the expenditures households incur as a result of sickness and use this to discuss the economic viability of arsenic mitigation options.

The impact of arsenic contamination on individuals and households is not just a matter of the presence of arsenic in ground water. Exposure depends on factors such as awareness and understanding of the problem, household and individual characteristics, actions taken to reduce exposure (referred to as avertive actions), and actions to mitigate the problem by seeking medical help. Thus, in this study, we also try to understand how and to what extent these various factors can explain the presence or risk of arsenic-related diseases among individuals. We assess risks at various stages of disease development. This information should be useful to policy makers and practitioners in targeting their clientele more effectively.

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[1] Department of Public Health and Engineering, Bangladesh, December 2005.

2. Background

Much of Bangladesh is a deltaic plain crisscrossed by mighty rivers such as the Ganges, Brahmaputra, Megna and the Teesta. The country has a population of approximately 129 million inhabitants (Census 2001) making it the most densely populated country in the world. Bangladesh is also one of the least developed countries in the world, with a per capita Gross Domestic Product (GDP) of US$ 444 in 2005 (BER, 2005). Nevertheless, Bangladesh has made significant strides in accelerating economic and human development. Access to clean water has been a major development target of the government of Bangladesh. Until the discovery of arsenic, it was thought that ninety seven percent of households had access to clean water—this number is now reduced to seventy four percent.[2]

According to the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP)—a major World Bank-funded government project—out of 4 million tube-wells installed in Bangladesh, 1.2 million have been found contaminated with arsenic (www.bamwsp.org). Fig. 1 shows the distribution of tube-wells with levels of arsenic monitored by the Department of Public Health Engineering of the Government of Bangladesh. The blue dots refer to tube-wells that have a concentration of arsenic of less than 0.5µg/liter, the red dots are tube-wells with a concentration of more than 50 µg/liter, the green dots are tube-wells with arsenic concentration between 0.5 to 4µg /liter and the peach dots represent concentration ranges from 4 to 50 µg/liter. What is startling is that the arsenic concentration level in 30-40 percent wells of the affected area is over 50 µg/liter (www.bamwsp.org, 2001). In terms of people affected, according to one estimate (DPHE 2005), there are some 38,380 *Arsenicosis* or other arsenic-affected patients in Bangladesh. However, this might be just the tip of the iceberg. For example, screening done by BAMWSP demonstrates that the figure might be as high as 1.1 cases of *Arsenicosis* per thousand people.

Several studies exist on arsenic contamination and the related geological, scientific, epidemiological, technological, and health aspects, which have been completed or are currently in the process of being completed. Smith, *et al*. (1999), for example, have shown that arsenic contamination may be responsible for bladder and lung cancer rather than other types of cancer. Zaldiver and Guiller (1977) have discussed, in the context of Taiwan and Argentina, how, "poor nutrition in children favors toxicity to arsenic." Since a number of the symptoms of *Arsenicosis* develop over time, the number of cancer patients (particularly those that continue drinking arsenic-contaminated water) is expected to dramatically increase in the coming years.

The primary pathway to *Arsenicosis* is prolonged exposure through drinking arsenic-contaminated water.[3] It usually takes 5 to 20 years to develop. Because of the slow process, the evolution of the disease is divided into several stages:

- *Primary Stage – Melonosis, Keratosis, Conjunctivitis, Gastroenteritis*. In the primary stage, an *Arsenicosis* patient may develop several symptoms, sometimes simultaneously, such as blackening of some parts of the body or the whole body (*Melanosis*); thickening and roughness of the palms and soles (*Keratosis*); redness of the conjunctiva (*Conjunctivitis*); inflammation of the respiratory tract; and nausea and vomiting (*Gastroenteritis*).

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2 http://lcgbangladesh.org/prsp/docs/257,2, An overview.

3 Absorption of arsenic through the skin is minimal. Thus hand-washing, bathing, laundry, etc., with water containing arsenic do not pose human health risks.

- *Secondary Stage – Lekonelanosis*, *Hyper-Keratosis,* Non-pitting *Edema*. If a patient continues to be exposed to arsenic-contaminated water, and if adequate preventive measures are not adopted, then the symptoms advance and become more visible including white intermittent dots within blackened areas (called *Leukonelanosis* or Rain Drop Syndrome), nodular growth on the palms and soles (*Hyper-Keratosis*), swelling of the feet and legs (Non-pitting *edema*), and peripheral neuropathy as well as liver and kidney disorders.
- *Final or Tertiary Stage* – In the tertiary stage, an *Arsenicosis* patient's physical condition deteriorates rapidly and the condition becomes irreversible. Gangrene of the distal organs or other parts of the body, cancer of the skin, lungs and urinary bladder and kidney and liver failure become manifest at this stage.

The National Institute of Preventive and Social Medicine (NIPSOM), Bangladesh, estimates that 50 million people are at risk of developing *Arsenicosis,* with *Melanosis* and *Keratosis* as the most common. According to them, people who are already diagnosed with *Arsenicosis* are reported to be either in the primary or in the secondary stage and the number of such patients is increasing.

Given the nature and the severity of the problem, the Government and other national and international institutions are engaged at various levels in providing aid to the people through technical and financial support for detection, research and mitigation projects. The World Bank, the Asian Development Bank and the Government of Bangladesh, with the help of many foreign governments, are working together on an investment plan worth 93.4 million dollars, for arsenic mitigation projects in Bangladesh. This investment, if successful, would eventually benefit nearly 24 million people.

3. Methods

3.1 Valuing the Benefits of Arsenic Safe Water

In this study, our first objective is to assess household level costs associated with arsenic exposure. Economists have attempted to estimate the costs associated with a decline in environmental quality or alternatively the benefits of improving environmental quality in a number of different ways and for numerous pollutants. A frequently used technique is to estimate the cost of illness from pollution, which generally includes the wage losses associated with sick days and the medical expenditures undertaken to recover from sickness resulting from pollution. There are many examples of this kind of study. For example, Tolley (1994) used the cost of illness approach to estimate willingness-to-pay (WTP) for reduction of human health problems and risks while Dickie and Gerking (1991) and Gerking and Stanely (1996) studied the value of air quality based on household expenditures on medical care. The study by Alberini, *et al.*, (1997) of air pollution impacts in Taiwan is among other notable contributions to estimating the cost of illness.

Another approach is to estimate the costs associated with avertive actions or the economic loss incurred by the household in attempting to avoid exposure to pollution. Abdalla, Roach and Epp (1992), for example, estimated averting expenditures to assess the costs of contaminated groundwater.

In Bangladesh, a recent important study on WTP for arsenic-safe water uses a third approach: contingent valuation. The study by Ahmad *et. al.*, (2002) estimates WTP for piped water supply projects. This study estimates that WTP for a community water stand post is Tk 51 per month, with an additional Tk 960 towards capital costs. For domestic connections, the mean estimated WTP is Tk 87 per month and Tk 1787 towards capital costs. For poor households, the costs are Tk 44 per month and Tk 838 towards capital costs for a stand post and Tk 68 per month and Tk 1401 towards capital costs for a home connection. This study has however come under some criticism on the grounds that poor households might not be able to pay for arsenic-free piped-water connections (www.arsenic poisoning in Bangladesh-India.htm, 2004). In our study, we adopt a cost of illness plus avertive expenditures approach—an approach discussed in Freeman (1993), which discusses different techniques to measure the health costs of environmental change.

This study follows the Freeman (1993) model of household production function to estimate the willingness-to-pay for arsenic-free water in Bangladesh. A household maximizes the utility subject to a full-income budget constraint:[4]

$$U(.) = U(X, L, S: H_i) \qquad (1)$$

Where, X is the amount of consumption of goods and services (private), L is the amount of time spent in leisure, S is the number of sick days and Hi is a vector of characteristics of the individual like education, health status, wealth, etc.

Following Freeman (1993), it can be shown that an individual determines his/her choice of consumption of goods and services and mitigation/averting activities based on income, cost of medical and averting activities, level of contamination in water, health status, and household characteristics. The marginal willingness-to-pay for a reduction in pollution (or an improvement in environmental quality) is given by:

$$MWTP = w\frac{dS}{dR} + P_A\frac{\partial A^*}{\partial R} + P_M\frac{\partial M^*}{\partial R} - \frac{\partial U / \partial S}{\lambda}\frac{dS}{dR} \qquad (2)$$

where, S is the number of work days lost due to sickness, A is averting activity undertaken, M refers to mitigating activities (illness and medicine related), R is the level of contamination, w is the wage, and P_A and P_M are the price of averting and mitigating activities and λ refers to the marginal utility of investment in mitigating and averting expenses to get rid of sickness. It should be noted that variables with asterisk (*) are measured at the optimal level.

Because of difficulties in estimating the last term in equation (2), which measures disutility from sickness, valuation studies often estimate a lower bound of the MWTP, as given in equation (3),

$$MWTP = w\frac{dS}{dR} + P_A\frac{\partial A^*}{\partial R} + P_M\frac{\partial M^*}{\partial R} \qquad (3)$$

where MWTP is the sum of a) cost due to work days lost, b) cost due to adoption of averting activities, and c) cost of mitigating activities.

4 For a detailed derivation, see Freeman (1993).

3.2 Risk of Disease and Socio-Economic Differences

Households respond to costs incurred from sickness in many ways. In some cases, other family members increase their work and/or there is a reduction in household consumption. Households also cope by drawing on cash savings, selling assets and obtaining loans. Furthermore, in a traditional society where social stratification is defined by kinship, assets and also ignorance, social exclusion can play an important role in influencing coping strategies. For example, since *Arsenicosis* in its initial stage is manifested as a skin disease, parents of brides with arsenic diseases find it difficult to gain appropriate grooms for their daughters. Exclusion is evident in other social interactions as well. For example, Asia Arsenic Network (2004) found that "*Arsenicosis* patients are refused jobs and water collection by neighbors or others." However, this type of unfortunate exclusion can have a positive impact when it comes to fighting arsenic contamination—the risk of social exclusion leading to the adoption of some mitigation measures. This, in turn, affects the risk associated with *Arsenicosis.* With the above scenario in mind, this study attempts to capture the influence of social and economic factors in determining the risk of *Arsenicosis.*

3.3 Data

To estimate the cost of illness, we undertook a survey of 5563 individuals from 878 households in two *Upazilla*s (sub-districts), Matlab and Laksman, in 2005. These *Upazillas* are located in the southeastern part of Bangladesh, which is the most arsenic prone region (see Fig. 1). To determine the sample frame, the database of the Department of Public Health Engineering (DPHE) was used and households were randomly chosen for the survey. Although the two *Upazillas* are located within a 50 km distance from each other, one of them, Matlab, is an area where health-related interventions are high due to its linkage with the International Centre for Diarrheal Diseases Research, Bangladesh (ICDDRB).

In terms of the level of contamination by arsenic, the two *Upazillas* are very similar as shown in Fig. 2. According to DPHE data, nearly 0.159 per cent of people in Laksman are affected by at least one of the variants of *Arsenicosis* while 0.106 percent of people are affected in Matlab. Only twenty four percent tube-wells in Matlab and thirty two percent tube-wells in Laksman are labeled safe (DPHE, 2005).

We used a two-step procedure to select the households for the survey. In the first stage, 900 tube wells were randomly chosen (450 from each *Upazilla*) for the survey from 7 Unions (three Unions from each *Upazilla*[5]). Since the same tube well is shared by several households, at the second stage, one household from each tube well user group was selected. The total number of households selected was 878.

The data collected for this study includes three general classes of information: a) household level information to determine the general characteristics of the household in terms of income and wealth; b) health, demographic, and socio-economic characteristics by individuals (each enumerator was trained to identify different variants of *Arsenicosis* based on symptoms of arsenic

[5] Administratively, Bangladesh is divided in to several tiers: Division, District, Upazilla, Union, Ward and Village. Unions are the second tier of local government institutions.

diseases); and c) work days lost, income loss, sick days, and averting and mitigating activities both at household level and at the individual level. Avertive activities here refer to actions taken by households to avoid use of contaminated water. Mitigating activities refer to doctor and hospital visits.

Tables 1 and 2 provide a brief summary of statistics at the individual and household level. The average age of the individuals in the sample is 28 years and the average year of schooling is 5 years[6] while height and weight of the individuals are 55.10 inches and 41.66 kg respectively. Fifty percent of the sample individuals are male.

To determine wealth status of the household, we collected a list of assets for each household. Using this list, the wealth index that was developed provides a relative scale on wealth for each household in terms of wealth status. The maximum value of the index is 100 and the minimum value is 0. A total of 43 types of assets were included in the calculation of the index. Of the 43 assets, 32 were listed as household assets and the other 11 were listed as productive assets. We present the wealth distribution of the sampled households in Fig. 3.

Non-governmental organizations in the area are involved in raising the level of awareness against drinking water from the arsenic-contaminated sources. Survey data shows that 32 percent of households attended such programs organized by NGOs. In Bangladesh, NGOs have covered nearly 50 percent of the rural population in terms of their activities. This number thus is not surprising.

In terms of sources of drinking water by the household, 46 percent of households in the sample use either a tube well or hand pump as the primary source of water for drinking. Only 11.5 percent people use water from deep tube wells as the source of drinking water. Less than 0.5 percent people use filters and only 0.2 percent use water from Arsenic Removal Plants (ARP). This clearly shows the extent of vulnerability of the local people in terms of *Arsenicosis.*

In the study area, a large number of tube wells (though not all) have been marked RED (unsafe for drinking) or GREEN (safe) by the government. However, survey data shows that 56 percent of households still drink water from RED-labeled tube wells. Further, since all the tube wells are not color-coded, it is possible that 86 percent of the households (see Table 2), who state that they drink water from shallow aquifer sources, may also be exposed to arsenic.

The survey also collected data on individuals, which is presented in Table 2. Our survey suggests that 5 percent of all the people surveyed have at least one of the various types of *Arsenicosis:* 4 percent have black spots or *Melanosis*, 3 percent have thickening or roughness of palms and soles (*Keratosis*), 2 percent have redness in eyes or *Conjunctivitis*, 2 percent have inflammation of respiratory tract, 0.43 percent have swelling of the feet and legs, .068 percent suffer from liver and kidney failure.

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[6] Households use several sources of water for drinking, cooking, bathing, and washing purposes. Based on their responses, this percentage was calculated keeping in view that households using shallow aquifers for drinking and cooking purposes are likely to be at risk.

Table 3 shows the percentage of cases found with variants of *Arsenicosis* amongst people who reported that they were sick from arsenic. Most of the individuals with arsenic-related diseases report their diseases to be in the primary stage. Fifty seven percent of sick individuals' symptoms related to *conjunctivitis*, 34.3 percent are suffering from *Keratosis*, 45.7 percent have respiratory problems and 46.4 percent people have reported gastrological problems. These figures suggest that the extent of *Arsenicosis* is much more severe than is commonly thought.

3.4 Empirical Model

In order to estimate the marginal willingness-to-pay for arsenic safe water given in equation (3), we need to estimate three functions. Freeman's (1993) model provides the basis for estimating a dose-response function for sickness and two demand functions for mitigating and avertive activities.

The demand for mitigating activities is given by:

$$M^* = M^*(y, w, P_M, P_A, R, Aw, H_S, Hi) \quad (4)$$

The demand for averting activities is given by:

$$A^* = A^*(y, w, R, P_M, P_A, Aw, H_S, Hi) \quad (5)$$

The dose-response function for workdays lost[7] (S) is:

$$S = S(R, M^*, A^*, Aw, Hs, Hi) \quad (6)$$

Where, w is wage income, y is non-wage income, P_M is cost (price) of mitigating activities, P_A cost (price) of averting activities, R is level of arsenic contamination, Aw is level of awareness, H_S is health status, and Hi is household characteristics. Mitigation activities, M, refer to actions undertaken to reduce the effects of arsenic related sickness and include medical expenses, fees paid to doctors or pharmacists, and travel costs. Averting activities, A, include adoption of different measures to reduce risk to arsenic. These included switching the source of water to another 'safe' surface or ground water source, harvesting rain water or using technologies such as the three pitcher method for purifying water.

Our survey data showed that households with arsenic affected patients did not have much of either averting or mitigating expenses, probably due to poor income status. Consequently, instead of using continuous data on mitigating or averting actions, we use binary variables. Thus, mitigating activities take the value 1 if an individual has any medical expenditures and zero otherwise. Similarly, avertive activities are a binary variable that takes the value 1 if the individual undertakes any avertive actions and zero otherwise.

Only 82 individuals out of more than 3260 individuals with some form of sickness reported workdays lost (WDL) due to sickness. The actual number of days lost was 5.29 per year. It is possible that due to poverty, perhaps, people could not afford to abstain from work. Thus in our empirical analyses, sickness is also treated as a binary variable, which takes the value of 1 if the individual reported arsenic-related sickness and 0 otherwise.

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7 Work days lost is equal to or less than the sick days.

The empirical model of equation (3) for estimating marginal willingness to pay is thus modified as below:

$$MWTP_i = w_i \times \overline{WDL_i} \times P_i(S \mid \Delta R) + \overline{M} \times P(M \mid \Delta R) + \beta_A \times P(S \mid \Delta R) \times P(A > 0)/z \quad \text{......} \; (7)$$
$$= \quad (A) \quad + \quad (B) \quad + \quad (C)$$

where P(S|ΔR) is the marginal effect or change in the probability of sickness (related to arsenic poisoning) for an individual due to changes in the level of arsenic poisoning, ΔR is expected changes in the dose of arsenic poisoning in water; *w* is average wage of the adult working population, $\overline{WDL}$ is the mean workdays lost, $\overline{M}$ is the mean mitigating expenditure per individual when he/she is affected with arsenic related diseases and *P(M|ΔR)* is the changes in the probability of incurring mitigating expenses due to changes in the level of exposure at the individual level. $\hat{a}_A$ is the estimated co-efficient of averting expenses when the level of arsenic changes and measures the marginal changes in the averting expenses due to changes in the level of exposure; *P(A>0)* is the probability of taking averting measures at the household level; the subscript i refers to individual member-based information; z refers to number of members in a household.

(A) $w_i \times \overline{WDL_i} \times P_i(S \mid \Delta R)$ measures the marginal impact in terms of income loss due to changes in the level of exposure to arsenic (ΔR);

(B) $\overline{M} \times P(M \mid \Delta R)$ measures the marginal effect on mitigating expenditure due to changes in the exposure to arsenic poisoning; and

(C) $\beta_A \times P(S \mid \Delta R) \times P(A > 0)/z$ measures the marginal effect on averting activities at the individual level for changes in the exposure. The first two terms measure the effect on averting expenses due to changes in exposure to risk.

4. Results

4.1 Estimating the Sickness Dose-Response Function

The probability estimates in equation (7) are derived using a probit model by maximizing the following log-likelihood function.

$$L = \sum (Y_i LnF(\mathbf{x}, \beta) + (1 - Y_i) Ln(1 - F(\mathbf{x}, \beta))) \quad \text{..} \; (8)$$

where x is a vector of independent variables and βs are the coefficients. x includes a) individual level information such as age measured in years (AGE and AGESQ), sex measured as a binary variable (SEX), and education measured in years (EDUC); b) household wealth index (WINDEX); and c) a binary variable indicating the presence of arsenic in drinking water (ARSCODE = 1 means the tube well is labeled RED while 0 means the tube well is labeled GREEN). The summary statistics of the variables used are presented in Table 1 and 2. F ( ) is the cumulative probability function for a probit model. Y_i =1 if an arsenic related disease is prevalent and = 0 if absent for i^{th} individual.

Using the probit model, we determine the marginal effect due to a change in the source of drinking water (from RED to GREEN).[8] The marginal effect $\Delta\hat{F} = (\hat{F}\,|_{ARSCODE=1}) - (\hat{F}\,|_{ARSCODE=0})$ shows the effect on changes in the probability of reducing incidence of an arsenic-related disease when a RED source of water is replaced by a GREEN source. Therefore, it measures the benefit in terms of disease prevalence by switching the source of water to a 'safe' mode.

Table 4 also shows that a change in the probability of sickness is associated with the age, gender and education of the individual. Since arsenic is a bio-accumulative element, the probability of *Arsenicosis* increases with age up to 55 years for both men and women (see Fig. 3). For females, the marginal effect is higher than for males implying that there is a larger gain in terms of reducing the probability of sickness when a women switches from RED to GREEN source of water. In terms of the probability of sickness, the model shows that a male has lower probability (by 0.86 percent) of getting sick than a female. This is probably caused by a) the poor health status of the female in a poor household; b) food habits where men often get more nutritious food than women.

The estimated model further shows that schooling years is negatively related with the probability of sickness, i.e., higher the level of education lower is the probability of getting sick (which could be caused by more awareness level). Each year of additional education reduces the probability of sickness by 0.27 percent. Finally, the impact of switching from RED to GREEN source of water reduces probability of sickness by 4.6 percent, by far the largest gain in terms of reducing sickness. These observations are valid for households using water from RED tube wells only.

4.2 Measuring Risks by Disease

Arsenicosis is the final stage of the disease arising out of drinking arsenic contaminated water for a long time. The disease itself is a slow growth disease and its manifestation in the human body varies significantly due to a) exposure; b) socio-economic and demographic characteristics of the individual; and c) cumulative intake of arsenic contaminated water.

To measure the risks of these variants of disease, we use a probit model to estimate how much of this impact could have been avoided if the affected people were given arsenic-free water. These results are presented in Annexure.

For *Melanosis*, Table 5 shows that if GREEN source of water can be introduced, then nearly 23 per 1000 persons could avoid the disease each year. If there is a delay in providing GREEN source of water in the area, there will be an increase in the number of patients (suffering from *Melanosis*) by 28 for every 10,000 individuals. Similarly, for every one unit rise in the index of wealth, number of patients could be reduced by 35 in 100,000. There appears to be no gender dimension to this disease, which means the probability will not change for either male or female. Finally, Table 5 also shows that educational attainment could influence the number of patients. For *Melanosis*, every one year increase in the level of education reduces the number of patients by 213 for every 100,000 people.

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[8] For detailed derivation see Greene (2003, p 674).

Table 5 shows that the family benefits the most in terms of incidence of all the diseases related to arsenic in water with an immediate switch to GREEN water sources. The next important variable for reducing incidence of various diseases comes from the cumulative impact of drinking water. Hence, earlier the switch is made the better off the population would be in terms of incidence of diseases. Education also plays a significant role in terms of reducing the incidence of arsenic-related diseases. The gender aspect of the disease is only visible in cases of swelling of legs and feet. For a man the number is 9 / 10,000 less than for a woman. Since we did not collect information on death related to arsenic, this analysis does not estimate the changes in probability of death due to *Arsenicosis*.

4.3 Medical Expenses from *Arsenicosis*

Mitigating activities include expenditures incurred due to sickness when any individual member in the household is affected by arsenic-related diseases. In the sample of 5563, only 88 reported medical expenditure related to arsenic, whereas 296 were suffering from arsenic-related diseases. Using the probit model, we estimate the probability of incurring mitigating expenditure due to exposure to arsenic. The estimated probit equation and the marginal effects are shown in Table 6.

Table 6 shows that the probability of incurring mitigating expenses is also influenced by the age of the individual, the square of his/her age, and the level of arsenic in drinking water (ARSCODE). It shows that the probability of incurring health expenditure will go up by 1.36 percent if the water source turns RED from GREEN. The co-efficient of Gender and Education is not significant but we kept these variables in the equation in order to avoid errors due to dropping relevant variables from the equation. In Table 6 the marginal value of AGE is positive. This implies that the individual's probability of incurring medical expenditure will increase with age or time. Unfortunately, the marginal value of 'sex' is not significant.

4.4 Averting Expenditure at the Household Level

Avertive expenses are incurred when adopting any alternative technology to reduce the impact of contamination. It is a precautionary step on the part of the household and expenses are often incurred at the household level rather than at the individual level. Aftab, Haque and Khan (2006) have shown that raising awareness on arsenic-related health risks leads to adoption of averting technologies.

In our study, only 196 households (out of 878 households in the sample) adopted at least one type of technology (the choice ranging from individual level to community level interventions) and reported operating and maintenance costs or installation costs or both. As a result, a majority of the households did not have any expenditure on averting technologies. Hence, when we estimated the demand for avertive activities, we found no statistical relationship with the adoption of averting technology at the household level and type of well used. We did not use the information on the avertive actions further while estimating the MWTP.[9]

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9 We wish to note that several other types of functional forms and variables were tried in order to determine the suitability of this function. In no case did we find ARSCODE to be statistically significant.

4.5 WTP for Swtiching Water Source from Red to Green

Using the calculation given in equation (7), and the coefficients of the Tables 1 and 2, we calculate the mean cost of illness for an individual at Tk 170.51 or $ 2.89 per annum. This is equivalent to Tk 1056.82 or US$ 17.91 per household per year. This measures annual willingness to pay for switching from RED to GREEN sources of water. This includes costs in terms of a) loss of income due to sickness (Tk 12.5 per annum for adults only) and b) mitigating expenditures for sick members in the family (Tk 158.01 per annum[10]). Table 9 presents the comparative analysis of WTP estimates from different studies. Among them, the study of Ahmad, *et al.,* (2002) is most relevant. This study used the CV method to estimate the WTP for arsenic free water at the household level using either home connection or a stand post. However, in this study, we did not measure WTP for any specific arsenic-free water at the household level.

Our estimate shows that even when we include a) costs due to lost working days, and b) cost of mitigation during sickness, the cost is lower than that estimated by Ahmad, *et al*., (2002). The difference is expected given the fact that we use the revealed preference method of estimation while Ahmad used the stated preference model to estimate the cost of damage. Other studies are not comparable because the WTP question is for different purposes. However, we present them in Table 9 to complete the illustrations.

4.6 Welfare Loss due to Arsenic Exposure

As stated earlier, mitigation of this problem will ensure the health and wellbeing of about 28-50 million people who are at risk. In financial terms, as estimated from willingness-to-pay, this is substantial. We estimated that the total medical expenditure from arsenic exposure is potentially in the range of 206.61 million to 368.94 million taka per year. In addition, there are costs in the range of 350 million to 625 million in terms of workday losses. Thus, total marginal willingness to pay lies between 556.71 million taka to 994.12 million taka per annum or nearly 0.6 percentof the income of the households (based on an average per capita income of $ 480). This means that if it is possible to mitigate this problem using suitable technology there is likely to be a net social gain of 9.44 to 16.85 million US$ per annum (see Table 10).

5. Discussion and Conclusions

This study has provided a key set of results in terms of risks and costs related to *Arsenicosis* caused by drinking water from arsenic-contaminated sources. We reiterate below some of the key findings of the study.

Our sample shows that the number of days lost in work due to sickness is 5.28 days per year. Thus, most of the households did not report a significant number of workdays lost[11] due to arsenic-related diseases. In terms of benefits, if a household switches to a GREEN source of water, then it could avoid only about $1 per year per household in terms of work days lost. This low value implies that adult members of households continue to work while they are sick. It also reflects their low wage earnings.

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[10] See Table 8

[11] Only applicable for adult individuals of the household.

An estimated 28-50 million Bangladeshis are at risk from arsenic-contaminated water. For a population of 28 million people exposed to arsenic risks, this is equivalent of 6.92 million workdays lost per year or a 350 million taka loss in income for affected individuals. For the higher estimate of 50 million people at risk, this is equivalent of 625 million taka loss in income. Hence, 350 million to 625 million taka is the total benefit in terms of avoiding workday losses by switching to GREEN source of water.

Given the range of population at risk, the equivalent savings in terms of medical expenditure avoided by switching to GREEN source of water is between 206.61 and 368.94 million taka per year. However, the probability of illness rises with age; therefore, this estimate is a lower bound in terms of medical expenditure. The actual cost will rise each year as the incidence of sickness will increase by nearly 4 for every 1000 population each year (see Table 4).

Annual total willingness to pay for switching from RED to GREEN sources of water is taka 1056.82 ($18) per household. We estimate the total welfare gain from switching to GREEN source of water by the exposed population to avoid arsenic related disease to be between 556.71 million to 994.12 million taka per year.

In terms of exposure to different diseases, switching to GREEN sources reduces the risk of *Melanosis*, raindrop and *Keratosis* diseases. A delay in adopting averting measures increases the risks of *Melanosis*, *Keratosis* and raindrop syndrome.

Education is an important tool in reducing the risk of *Arsenicosis* diseases in Bangladesh. Similarly, reduction of poverty is another important policy variable which can also successfully reduce the risk of arsenic-related diseases. Consequently, poverty reduction and education should be pursued as a policy to reduce the impact of arsenic poisoning.

Females are likely to be more affected by swelling of legs disease. This is probably because this disease often goes undetected for a longer period of time since women do not report to a doctor in the initial stages of the disease. As a result, we see more female patients in this category.

Since the study estimates the costs of arsenic exposure, it is useful to see how the costs of arsenic exposure compare with the costs of mitigation. Currently, there are two types of arsenic mitigation options available in Bangladesh. In the first category, there are community based mitigation techniques, which include arsenic and iron removal plant, pond sand filters, deep tube wells and piped water supply. These mitigation options require the involvement of institutions (like NGOs, Government agencies, etc.) to bear the initial cost of investment, which can range from $2,000 to $240,000 for 100 households (see Table 12). The dynamics of establishing institutions to run these community-based mitigation options is not simple and needs to be taken into consideration when assessing the feasibility of such investments.

Mitigation can also be undertaken at the household level using various techniques such as the three pitcher method and use of *Shapla* or *Sono* filters, etc. These options cost between $4 to $4250 (initial capital) plus $0.5 to $25 annually for operation and maintenance. Our study suggests that the less expensive of these options, i.e., those that cost less than $18 annually may be acceptable to households if the initial costs are low or subsidized. The Government of Bangladesh is yet to finalize any specific technique as suitable for all households. One factor that should be taken into account in making any such decision is household willingness to pay for mitigation. Clearly, the costs of mitigation, if they are to be acceptable to households, should be less than the costs incurred by exposure to arsenic.

Arsenic poisoning is a major public health concern in Bangladesh. However, much of the social and economic story of arsenic is unknown. People drinking from the same water source for the same period of time may not be affected similarly because of their health and hygiene standards. People of the same age too are not affected similarly because of differences in body mass and food habits. As a result, the challenge can be said to contain both social as well as strictly medical dimensions when it comes to seeking remedies.

The costs of arsenic contamination are large and the risks vary by socio-economic categories. In the absence of this kind of detailed information, identification of causes may be difficult and all the causes could be lumped together into one cause—arsenic contamination. Or all the solutions could be merged into one, i.e., improving the water quality. Such a quick fix, we propose, is neither efficient nor desirable to society.

6. Acknowledgements

This study has been conducted with financial support from the South Asian Network for Development and Environmental Economics (SANDEE). I am grateful to my Supervisor Professor A K Enamul Haque for providing intellectual and technical inputs, Dr Priya Shyamsundar for her meticulous reading of the queries on several drafts, and also to Dr. Sajjad Zohir for his insightful comments throughout the study. The feedbacks and the comments of resource persons Jeff Vincent, Maureen Cropper, Priya Shyamsundar, M N Murty and others of SANDEE have enriched the study at various stages. I am thankful to Mr Prashant and Mr Rahman for their encouragement at the initial stage of conceptualization of this study. I would also like to express my thanks to the SANDEE Secretariat, especially Mr Manik Duggar, Ms Anuradha Kafle and Ms Kavita Shrestha, for their encouragement and support during different stages of this study.

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TABLES

Table 1: Household Level Information

Household Information	Mean	SD	N=878 Remarks
Wealth index[12]	51.64	12.40	index
Family size	6.33		Number of persons
Family size (adult >= 14 years)	4.53		
Technology adoption (averting)	19.88	0.40	Percent
Cost of technology (averting)	3217	3279.44	Taka
Medicare bills (annual)	11618.116	7844	Taka per year
Operation and maintenance cost (averting technology)	13.04	75.53	Taka per year
Participation in NGO activities	32.00	0.71	Percent
Highest educational achievement in the family	9.4	3.1	Years of schooling
Percent of families reported sickness	19.36	0.40	Percent
Percent of families drinking water from shallow aquifer sources	86.23	0.345	percent

Source: Survey Data.

12 Based on the information found in the survey, the study also constructed a we alth index for each household using construction of HDI by UNDP.

$$WI_i = \left[\frac{\sum_{1}^{43} a_{ij} - \min(a_{ji})}{\max(a_{ji}) - \min(a_{ji})} \times 100 \right]$$

where, j refers that the holding of i number assets (a) and $a^{ij} = 1$ if the ith household has the j^{th} asset, and 0 = otherwise i = 1,2,3, … m representing households, and j = 1,2,3, … n representing the assets available at the household. The minimum of a^{ji} means holding by jth household of the lowest number of i assets.

Table 2: Individual Level Information

Individual Level Information	Mean	SD	N = 5563Comments
Age	27.49	20.251	Years
Gender	50.40 percent		Male
Education	5.17	4.150	Years
Percent mitigating	12.21		Percent
Sick days (non working days [WDL])	5.29	2.016	Days per year
Melanosis (incidence)	3.52		Percent
Keratosis (incidence)	2.77		Percent
Conjunctivitis (incidence)	1.76		Percent
Inflammation of RT (incidence)	1.87		Percent
Hypo-pigmentation (incidence)	2.88		Percent
Hyper Keratosis (incidence)	1.10		Percent
Non-pitting *Edema* (incidence)	0.43		Percent
Liver and Kidney failure (incidence)	0.068		percent

Source: Survey 2005

Table 3: Distribution of Arsenic Related Diseases among Sick Households

Different Arsenic Diseases	Arsenic-Related Diseases	Percent of Cases
Primary Stage	***Melanosis* or black spots in the body**	**8.6**
	Keratosis or thickening of the palms and soles	34.3
	Redness of the eye or *Conjunctivitis*	58.6
	Inflammation of the respiratory system	45.7
	Gastrointestinal problem	46.4
Secondary Stage	**Hypo-pigmentation or white spots**	**5.7**
	Hyper-Keratosis or nodular growth	15
	Swelling of the feet and legs	12.1
	Peripheral Neuropathy	17.1
	Liver or kidney disorder	7.1
Tertiary or Final Stage	**Gangrene of the distal organs**	**3.6**
	Cancer of the skin, lung or urine	2.9
	Liver or kidney failure	2.1

Source: Survey 2005

Table 4: Estimating the Probability of Sickness (Probit Model)

	Coeff	Std error	z-value		Marginal effect	Std error	
AGE	0.0516074	0.0053757	9.6	***	0.0041361	0.0004057	***
AGE SQ	-0.0004610	0.0000634	-7.27	***			
SEX	-0.1049217	0.0610308	-1.72	*	-0.0085767	0.0049977	*
EDUC	-0.0337094	0.0076790	-4.39	***	-0.0027508	0.0006418	***
ARSCODE	0.4561030	0.0630928	7.23	***	0.0467376	0.0077768	***
CONSTANT	-2.5410500	0.1121453	-22.66	***			

*NOTE: * means significant at 10% level, ** means significant at 5% and *** means significant at 1% level.*
Number of observations= 5554, LR chi-square (5) = 240.28,
Prob > chi-square = 0.0000, Pseudo R^2=.1039 Log Likelihood = -1035.6753

Table 5: Probability of Reducing Health Impacts by Supplying Arsenic Free Water for Different Arsenic-Related Diseases

Disease Name	Reduction in Number of Patients if GREEN Water Sources were Available	Increase in Number of Patients for Every Year of Delay in Switching Water Source to GREEN	Reduction in Number of Patients by Reducing Poverty	Gender Sensitivity of *Arsenicosis*:	Reduction in Number of Patients through Education (for each schooling year)
			Primary Stage		
Melanosis	-23 / 1000	28 / 10,000	-35 / 100,000		-213 / 100,000
Keratosis	-15 / 1000	23 / 10,000	-24 / 100,000		-198 / 100,000
Conjuctivitis	-13 / 1000	12 / 10,000	-16 / 100,000		-127 / 100,000
Inflammation of respiratory tracts	-9 / 1000	15 / 10,000	-14 / 100,000		-126 / 100,000
			Secondary Stage		
Raindrop syndrome	-25 / 1000	22 / 10,000	-26 / 100,000		-13 / 100,000
Hyper Keratosis	-10 / 1000	9/ 10,000	-9 / 100,000		-62 / 100,000
Swelling of legs and feet	-2 / 100,000	7 / 10,000	-3 / 100,000	-9 / 10,000 women	-9 / 100,000

NOTE: Calculation by the Author of this paper based on Probit equations

Table 6: Estimating Probability of Incurring Medical Costs (Probit Estimates)

	Coeff	Std error	z-value		Marginal effect	Std error	
AGE	0.044283	0.008252	5.37	***	0.001092	0.0001850	***
AGE SQ	-0.000355	0.000091	-3.89	***			
SEX	0.053080	0.093393	0.57	NS	0.001331	0.002344	NS
EDUC	-0.031557	0.011711	-2.69	***	-0.000791	0.000306	***
ARSCODE	0.409407	0.094356	4.34	***	0.013621	0.003980	***
CONSTANT	-3.113758	0.188855	-16.49	***			

*NOTE: * means significant at 10% level, ** means significant at 5% level, and *** means significant at 1% level, NS means not significant. Number of observation= 5554, LR chi-square (5) = 92.03, Prob > chi-square = 0.0000, Pseudo R^2=.1018, Log Likelihood = -406.03703*

Table 7: Calculation of Cost of Illness or Welfare Gain

Indicators	Estimated Value	Comments
Average wage	50.623	Weighted Average of Wages
Average sick days loss per individual per year	5.289	Days per year
P(S| DR)	0.0467	Coefficient from Table 4
Mitigating expenditure	11,618.12	Per year
p(m| DR)	0.0136	Coefficient from Table 6
Aver exp	-	
p (A > 0)	0.0524	

Table 8: Lower Bound of Willingness to Pay to Avoid Arsenicosis

	Lower Bound of WTP (In Tk)	Lower Bound of WTP (In US $ = Tk 59)
Individual per annum	**170.51**	2.89
Loss on income due to lost work days	12.50	0.21
Mitigating Expenses	158.01	2.68
Household level expenses	**1056.82**	17.91
Loss on income due to lost work days	56.64	0.96
Mitigating Expenses	1000.18	16.95

Source: Calculation done by the Author
NOTE: Averting expenditure is not included since it has not been found statistically significant.

Table 9: Comparison of WTP from Other Studies

Issue for WTP	Method/Approach	Value per Household per year	Source
WTP for arsenic free water	Cost of Illness (Workday loss + Mitigation expenses) (per household)	Taka **1056.82** or ($17.91)	This study
WTP for Arsenic Free Drinking Water in Rural Bangladesh	Contingent valuation method(home connection)	Taka 2,831.00 or ($48.27)	JK Ahmad, JK, *et. al.*, (2002)
WTP for urban clear air in Kanpur, India	Contingent valuation (standpost)	Taka 1572 or ($26.73)	Ahmad, JK, *et. al.*, (2002)
WTP for faecal coliform free drinking water in Delhi, India	Cost of illness Cost of illness	Rs 850.97 ($21) Rs 1094.31 ($26)	Gupta, Usha (2005) Dasgupta, P (2005)

Table 10: Total WTP or Welfare Loss of Bangladesh

Extent of Affected	Population are at RISK in Bangladesh (In Million)	Probable Number of People Affected (In Million)	Total Number of Sick Days (In Million)	WDL (million Taka)	Mitigating Expenditure (million Taka)	Welfare Loss (million Tk)	Welfare Loss (million US $)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOW	28	1.3076	6.92	350.10	206.61	556.71	9.44
AVERAGE	35	1.6345	8.64	437.62	258.26	695.89	11.79
HIGH	50	2.335	12.35	625.18	368.94	994.12	16.85

Calculation Notes:

Col 3= $P(S \mid \Delta R) \times Col\ (2)$ *where* $P(S \mid \Delta R) = 0.0467$ *[equation 8.1]*

Col 4 = Mean [WDL] $\times$ *Col (3), where mean[WDL], Table 2, row 6.*

Col 5 = Col 3 $\times$ *mean[WDL]* $\times$ *Mean[wage], mean[wage=50.62[13]]*

Col 6 = Mean [Medical expenses] $\times P(M \mid \Delta R) \times$ *Col 3, where Mean[Medical exp] from Table 2, row 4,* $P(M \mid \Delta R)$ *from Equation 9.1.*

Col 7 = Col 5 + Col 6

Col 8 = Col 7 / 59 where 1 US$=59 Taka at the time of survey.

13 Calculated using weighted average for manufacturing, agriculture and construction wage rates from national labor survey

Table 11: Probit Estimates of Arsenic-Related Disease of Primary and Secondary Stages with Marginal Effects

	Primary Stage of *Arsenicosis*								Secondary Stage of *Arsenicosis*					
	Melanosis		*Keratosis*		*Conjunctivitis*		Inflammation of RT		Raindrop syndrome		*Hyper-Keratosis*		Swelling of Legs and Palms	
	Coeff	ME	Coeff	ME	Coeff	ME	Coeff	ME	Coeff	ME	Coeff	ME	Coeff	ME
Age in years	0.0489	0.0028	0.0549	0.0023	0.0462	0.0012	0.0518	0.0015	0.0489	0.0022	0.0470	0.0009	0.1339	0.00072
z value	7.94***		7.8***		5.83***		6.47***		7.25**		4.77***		3.64***	
Age square	-0.0004		-0.0005		-0.0004		-0.0005		-0.0004		-0.0004		-0.0019	
z value	-6.11***		-6.13***		-4.25***		-5.06***		-5.51**		-3.88***		-3.44***	
ARSCODE (1=red, 0=green)	0.3311	0.0229	0.3050	0.0154	0.3918	0.0130	0.2528	0.0087	0.4242	0.0249	0.3978	0.0100	0.0810	-0.00001
z value	4.56***		3.8***		4.23***		2.73***		5.54**		3.74***		0.47	
Education in years	-0.0374	-0.0021	-0.0473	-0.0020	-0.0503	-0.0013	-0.0431	-0.0013	-0.0225	-0.0010	-0.0329	-0.0006	-0.0335	0.00023
z value	-4.3***		-4.84***		-4.22***		-3.86***		-2.45**		-2.46**		-1.6	
Wealth Index	-0.0062	-0.0004	-0.0056	-0.0002	-0.0062	-0.0002	-0.0048	-0.0001	-0.0058	-0.0003	-0.0049	-0.0001	-0.0105	-0.00009
z value	-2.19**		-1.8*		-1.67*		-1.36		-1.88*		-1.12		-1.59	
Gender (1=male, 0=female)												-0.3366	-0.00095	
z value													-1.98**	
Constant	-2.3541		-2.5803		-2.6902		-2.7543		-2.6127		-2.9110		-3.7484	
z value	-12.63***		-12.13***		-10.67***		-11.23***		-12.53**		-9.67***		-5.62***	
No of obs	5563		5563		5563		5563		5563		5563		5563	
LR Chi-square	156.8200		159.7200		123.4300		108.9400		142.4900		59.7400		42.5700	
Log Likelihood	-769.8704		-624.3782		-431.2306		-462.4177		-654.2288		-306.0889		-133.3265	
Pred (p-Hat) at mean		0.0245		0.0169		0.0094		0.0112		0.0186		0.0067		0.00078

*NOTE: ME - Marginal Effect, *** denotes coefficient is significant at 1% level of significance, ** denotes significance at 5%, and *denotes significance at 10%. Dependent variable is the probability of being affected by the disease.*

Source: Field Survey.

Table 12: Unit Cost of Different Types of Arsenic Removal/Mitigating Technologies

Name of Technologies	Type	Capital Cost/ Unit (USD)	Operation and Maintenance Costs	Unit Cost* (Family/Year) (USD)
Sono 45 – 25 Filter	Household	13	0.5 to 1.5	14
Shapla Filter	Household	4	11	15
SAFI Filter	Household	40	6	46
Bucket Treatment Unit	Household	6 to 8	25	35
Sidko	Community (75 Household)	4250	10	66.67
Alternative water supply				
Iron-Arsenic Removal Plant	Community (10 Household)	200	1	21
Rain Water Harvesting		30	5	0.151
Deep Tube Well		120	4	0.151
Pond Sand Filter		117	15	0.161
Dug Well		102	3	0.256
Piped Water Supply		5872	800	0.375
Arsenic Removal Unit for Urban Water Supply	6000 Household	240000	1 - 1.5	40.00

Source: *worldbank.org/INTSAREGTOPWATRES/Resources/ArsenicVolII_PaperIV.pdf*
Note: ** calculation by author.*

FIGURES

Figure 1: Distribution of Tube Wells with Arsenic Levels

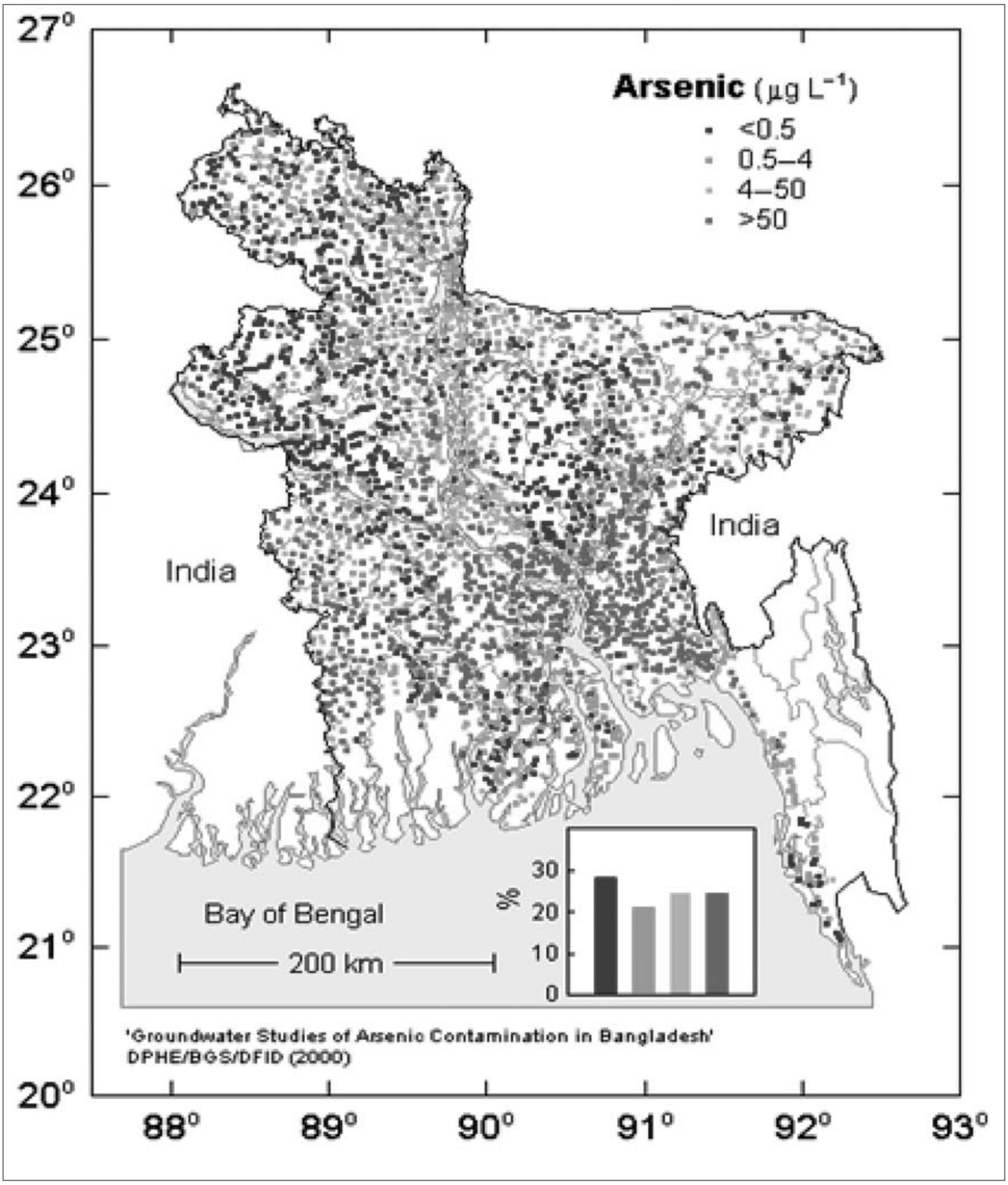


Figure 2: Wealth Index of the HH

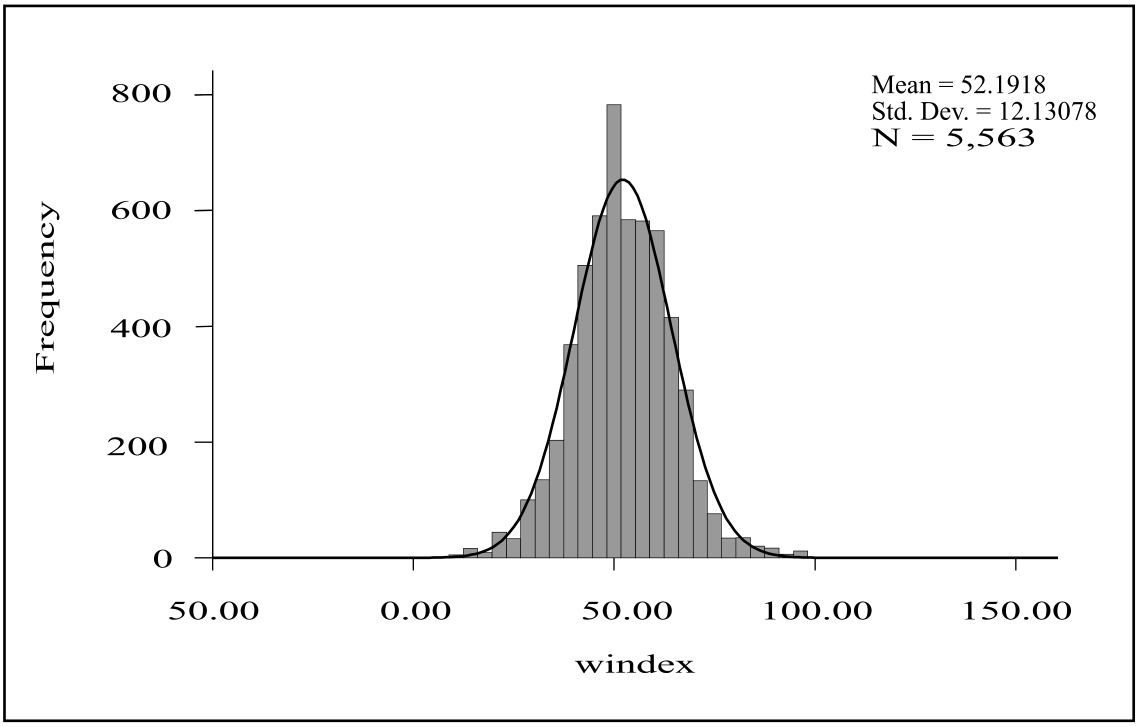
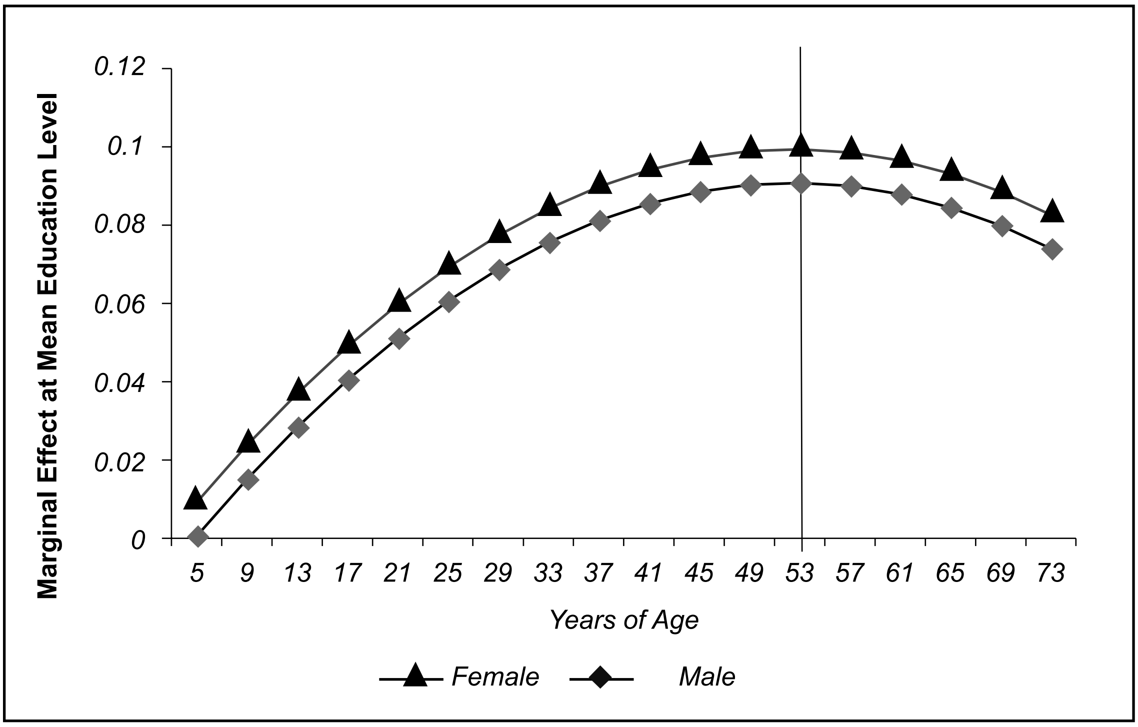


Figure 3: Marginal Effect by Age



APPENDIX

HH Survey Questionnaire

Economic Research Group (ERG)

And

Department of Economics, North South University

SANDEE Sponsored Research Project

on

“The Economic Cost of Arsenic Contamination in Drinking Water and an Analysis of Coping Strategies for Averting a Social Disaster - Policy Options for Bangladesh”

1.1.1.1. Information on the Survey Area and Respondents

<table>
<tr><td rowspan="2">Study Code</td><td colspan="2">Thana</td><td colspan="2">Union</td><td colspan="2">Village</td><td colspan="2" rowspan="2">Name of the Head of HH :</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TW</td><td colspan="2"></td><td colspan="2">As (Mg/L)</td><td colspan="2"></td><td>Name of the Respondent:</td><td>Rel. with HH</td></tr>
<tr><td colspan="2" rowspan="2">DPHE card</td><td colspan="3">1= Yes; 2 =No</td><td colspan="2">Date</td><td></td><td></td></tr>
<tr><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="7">Village Name :</td><td colspan="2">Name of the Investigator:</td></tr>
<tr><td colspan="7">Ward/ Mouza No :</td><td colspan="2">Date of Survey:</td></tr>
<tr><td colspan="7">Union:</td><td colspan="2" rowspan="2">Location of the Homestead:</td></tr>
<tr><td colspan="7">Thana :</td></tr>
<tr><td colspan="7">District:</td><td>Name of the Supervisor</td><td>Signature</td></tr>
<tr><td colspan="7"></td><td></td><td></td></tr>
<tr><td colspan="7"></td><td></td><td></td></tr>
</table>

1 = Respondent Self, 2 = Husband/ Wife, 3 = Brother / Sister, 4 = Son /Daughter, 5 = Uncle /Aunt, 6 = Grand father/ Mother, 7 = Others

Q1. **(i) Number of the members of the HH: Total ———— (ii) Male : ————**
(iii) Female :—————

Member ID	Name of the Members (1,3,5..... Male; 2,4,6,..... Female)	Age (Years)	Sex 1 Male 2 Female	Marital Status 1=Never Married 2 = Married 3 = Widow / Widower 4 =Divorced 5 =Separated	Height (Inch)	Weight (kg)	Educational Attainment (Class passed/ completed)	Work Status *	Relation-ship with the head of HH	Collects or brings water for HH use 1 = Yes 2 = No
1	Respondents own									
2	Respondents own									

Relationship with the HH

1 = Parents
2 = Husband/Wife
3 = Brother/Sister
4 = Uncle/Aunt
5 = Son/Daughter in Law
6 = Cousin
7 = Nephew/Niece
8 = Grandfather / Mother
9 = Grand child
10 = Not related/ other

Education:*

1 – 9 Class I - IX ;
10 SSC/ Equivalent ;
11 Dakhil /Equivalent;
12 HSC / Equivalent;
13 Alim / Equivalent
14 Graduate/ Equivalent ;
15 Medical/Engineering;

Work Status:

1 = Disabled/Children/Unable;
2 = Student / with casual participation;
3 = Student with active participation in productive works;
4 = Engaged in HH productive works;
5 = HH +(cash) income-earning activities ;
6 = HH only ;
7 = Unemployed,
8 = Others

Q 3.1 Information on HH Assets:

For Personal Consumption Purpose

Name of the Assets	Assets Code	Do You Hold this Asset? 1= Yes, 2 = No
Personal living house (Excluding land)	3.1.1	
Big tree	3.1.2	
Bucket/*Lota*/*Goti*	3.1.3	
Stove/ Heater/Gas burner	3.1.4	
All cooking materials (metallic)	3.1.5	
Bed / *Khat*/ Native bed (*Chowki*)	3.1.6	
Chest of drawer/ Showcase/ Meat safe/Cloth rag or *Alna*	3.1.7	
Table/ Chair/ Bench or Tool	3.1.8	
Fan / Electric Iron or Calendar	3.1.9	
Radio/ Cassette Player/CD Player	3.1.10	
Wall clock/ Wrist Watch	3.1.11	
TV/ VCD	3.1.12	
Freezer	3.1.13	
Ornaments (Gold/ Silver)	3.1.14	

List of the Productive Assets (For Earning Purpose)

Name of the Assets	Assets Code	Do You Hold this Asset? 1= Yes, 2 = No
Sewing machine	3.1.15	
Bi-cycle	3.1.16	
Rickshaw / Van	3.1.17	
Motor cycle	3.1.18	
Mobile Phone / Land Phone	3.1.19	
Hand Pump/ TW	3.1.20	
Paddy (Current storage)	3.1.21	
Rice (Current storage)	3.1.22	
Floor/ Wheat (Current storage)	3.1.23	
Domestic animal (For personal use)	3.1.24	
Duck/Hen/Bird (For personal use)	3.1.25	
Other (——————————————)	3.1.26	
Other (——————————————)	3.1.27	
Other (——————————————)	3.1.28	

Name of the Assets	Assets Code	Do You Hold this Asset? 1= Yes, 2 = No
Sewing machine	3.1.29	
Rickshaw / Van	3.1.30	
Mobile phone / Land phone	3.1.31	
Fishing net	3.1.32	
Electric iron	3.1.33	
Hand pump / TW	3.1.34	
Irrigation equipments	3.1.35	
Boat	3.1.36	
Cattle	3.1.37	
Duck and hen	3.1.38	
Other agricultural equipments	3.1.39	
Other vehicle	3.1.40	
Charcoal machine	3.1.41	
Others (---------------------------)	3.1.42	

3.3 Ownership of Different Water Sources

Name of the end-uses	Sources of End-Uses (Code*)	No. of Years in Use	Current Ownership Pattern	For how long the current ownership is prevalent	Prior Source	Ownership
		Years	1 Govt. 2 NGO 3 Community 4 Personal 5 Institution and others	In Years	1 Govt. 2 NGO 3 Community 4 Personal 5 Institution and others	1 Govt. 2 NGO 3 Community 4 Personal 5 Institution and others
Drinking						
Washing						
Bathing						
Cooking						
Irrigation						
Others (Gardening, and others)						

Sources:
1 = Shallow tube-wells / Hand pumps
2= Community owned filters
3 = A.R.P's, 4 = Tube well
5 = Deep tube-well
6 = Dug wells, 7 = Pond ;
8 = Pipeline supply water.
9= River
10 = Rain water harvesting;
11= Household filters
12 = Mineral water
13= Purifying water through filter
14 = Other sources

Water Related Information

Q 4. Do you follow any purification method?

1	Yes	
2	No >>8.1	

Q 5. Why are you purifying the water?

Serial No.	Reasons	1 = Yes 2 = No
1	Arsenic Free	
2	Bacteria free	
3	Iron free	
4	Any other free	

Q 6. Water Purification Methods

Sl. No.	Different Methods	1 Yes 2 No >> next method	In Tk.		Length of Drinking Water from Same Source	
		Do you think it removes arsenic?	Money Spent			
			Initial	Recurring	Before Sick	After Sick
			Tk./ Month	Tk./ Month	How many Years?	How many Years?
1	Boiling					
2	Filter : Cartridge Candle					
3	Filter : iron filter					
4	Digging deep tubewell					
5	Treating with chemicals					
6	Storage					
7	Digging dug well					
8	Alum					
9	3 Pitcher method					
10	Others ( )					

Q 7. Different Uses of Water and Related Information

Serial No.	End Uses	Collection Cost per HH		Quantity of Water Used per Day	
				In liter/bucket	
		Tk./ Month		General	
		Initial	Recurring	Before Sick	After Sick
		Tk./ Month	Tk./ Month	How many Years?	How many Years?
1	Drinking	Dry season	Wet season	Dry season	Wet season
2	Cooking				
3	Washing utensils				
4	Bathing				
5	Irrigation/Gardening				
6	Animal washing				
7	Others				

Coping Behavior towards the Adoption of Alternative Technologies

Q 8. If the main sources of water is tube-well then has the dangerous level of arsenic been identified in drinking water of your tube-well?

1	Yes	
2	No	
3	Unknown	

Q 9. Information on the Presence of Arsenic in Different Sources of Water

Serial no.	All Sources of Water	Is this source arsenic or otherwise ontaminated?	Who informed you?
		1 = Yes 2= No 3= Do not know	1= DPHE(GO) 2 = LGRD (GO) 3 =NGO 4=Media 5 =Relatives/ Neighbors 6 = Others
1	Community Owned Filters		
2	Oxidation / Iron Filter		
3	Arsenic Removal Plants (A.R.P's)		
4	Purifying Filter of Shallow Tube-Wells / Hand Pumps		
5	Deep Tube-Well		
6	Dug Wells		
7	Pond		
8	Supply Water		
9	Rain Water Harvesting		
10	HH Filter		
11	Mineral Water		
12	Pond Sand Filter		
13	Storage		

Q10.1 Have you adopted any alternative technology for averting purpose?

1	Yes>> 10.3	
2	No	

Q 10.2 Reasons for not Adopting Any Technology

Serial No	If answer is No, then what type of technological alternatives you choose?	What are the reasons for not using the specific technologies (Codes in Below **)					Future choices for technology
Sl. No	1 Yes 2 No >> Q (III)						
1	Community Owned Filters						
2	Oxidation / Iron Filter						
3	Arsenic Removal Plants (A.R.P's)						
4	Purifying Filter of Shallow Tube-Wells / Hand Pumps						
5	Deep Tube-Well						
6	Dug Wells						
7	Pond						
8	Supply Water						
9	Rain Water Harvesting						
10	HH Filter						
11	Mineral Water						
12	Pond Sand Filter						
13	Storage						
14	Other ( )						

1 = Shortage of money
2 = Not available in the market
3 = Do not know the effectiveness
4 = Extent of sickness is not significant
5 = Not easily manageable
6 = Lack of GO activities to make aware
7 = Lack of NGO activities to make aware
8 = Others

Q10.3 Uses of the Different Arsenic Removal Technologies

Serial No	10.3.1	10.3.2	10.3.3	10.3.4	10.3.5	10.3.6	10.3.7	10.3.8	10.3.9	10.3.10	10.3.11	10.3.12	10.3.13	10..3.14
						If answer is yes, then at present					If HH has personal technology, then			
	Name of all sources of the drinking water	Do you use the following tech? 1 =Yeas; 2 =No	For how many years have you been using?		Do you collect water from the outside of the house?	From how far do you collect water?	How much time do you spend daily?	Collection costs	Ownership	Costs to establish the technology	Source of the expenses			Maintenance cost
			1 = Indefinite 2 = Year		1 = Yes, 2 = No >> 10.2.9	In meter	Hour/ day	(Taka)	1 = Personal 2 = Govt. 3 = NGO 4 = Community	Tk.		Code		Tk./Year
			Code	Year										
1	Community Owned filters													
2	Oxidation / Iron Filter													
3	Arsenic Removal Plants (A.R.P's)													
4	Purifying Filter of Shallow Tube-Wells													
5	Deep Tube-Well													
6	Dug Wells													
7	Tap Water Supply													
8	Rain Water Harvesting													
9	HH Filter for Purifying													
10	Pond Sand Filter													
11	Storage													
12	Other ( )													

Sickness/*Arsenicosis* Related Information

Q 11. Is any member suffering from arsenic contamination?

1	Yes	
2	No	
3	Unaware	

Q 12. Has any one died in the household due to arsenic poisoning?

1	Yes	
2	No	

Q 13. If yes, then, the information on *Arsenicosis* patients

Member ID	Several Symptoms of Arsenic Affected Patients													When Detected first?	Who Detected	How was the disease detected	If not treated then reasons			
	Primary Stage					Secondary Stage					Tertiary Stage									
	Black spots in the body	Thickening and roughness of the palms and soles *Keratosis*	Redness of the conjunctiva *Conjunctivitis*	Inflamm-tion of the respiratory tract	Nausea and vomiting-*Gastro-enteritis*	White black spots in body	Nodular growth on the palms and soles *Hyper-Keratosis*	Swelling of the feet and legs *(Non-pitting edema)*	*Peripheral neuropathy*	Liver and kidney disorders	Gangrene of the distal organs or other parts of the body	Cancer of the skin, lungs and urinary bladder	Kidney and Liver failure	Year	1 Health worker 2 Doctor 3 NGO worker 4 others	1 Diagnosis 2 Without Diagnosis	1 Shortage of money 2 Far away of hospital 3 Doctors are not available in their locality 4 Unaware 5 Not specified 6 Others			
	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes	1 Yes							
	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No	2 No							

14. Information on Sickness due to *Arsenicosis* and other Diseases (In last 3 months)

Member ID.	How many days he/ she cannot work due to sickness		History of Major Diseases or Present Health Status*					Cannot Work /No. of Working Days Lost		Income Lost		
	Arsenicosis	Other Sickness	Number of Chronic Diseases	Codes of the Chronic Diseases **				*Arsenicosis*		Amount in Tk./ Month		
	Days/Month							Days/Month				

15. Information on Arsenic Mitigation and Transportation Expenditures (last 3 months):

15.1 Allopathic

Member ID.	Diseases		Whether Consulted a Doctor	If yes, then Monthly expenditure for Medicare									
				Domicile				Hospital			Sources of Expenditure (In Tk.)		
	1 *Arsenicosis* 2 Others		1 Yes 2 No	Number of Visits	Doctor visit Fee (In Tk.)	Treatment (In Tk.)	Transport (In Tk.)	Doctor Visit Fee (In Tk.)	Treatment (In Tk.)	Transport (In Tk.)	Code **		

***1 = Borrow*
2 = Using the cash and mobilizing savings
3 = Suspending expenditure (Eg. Education)
4 = Sale of livestock / assets
5 = Income diversification
6 = Cut back on purchase of non-essential products
7 = Free care
8 = Micro-credit
9 = Eating less in terms of quantity
10 = Support from Community
11 = Others

15.2 Homeopathic/Herbal

Member ID.	Diseases		Whether Consulted a Doctor	If yes, then Monthly expenditure for Medicare									
				Domicile				Hospital			Sources of Expenditure (In Tk.)		
	1 *Arsenicosis* 2 Others		1 Yes 2 No	Number of Visits	Doctor visit Fee (In Tk.)	Treatment (In Tk.)	Transport (In Tk.)	Doctor Visit Fee (In Tk.)	Treatment (In Tk.)	Transport (In Tk.)	Code **		

***1 = Borrow;*
2 = Using the cash and mobilizing savings;
3 = Suspending expenditure (Eg. Education);
4 = Sale of livestock / assets;
5 = Income diversification;
6 = Cut back on purchase of non-essential products;
7 = Free care;
8 = Micro-credit
9= Eating less in terms of quantity;
10= Support from Community;

Q 16. Awareness related information

Have you got the DPHE card on the information of test result of TW	What are the color codes of the tested TW?	Have you been drinking water from the 'red marked' TW?	If 'Yes' then what are the reasons (Codes)				
1 = Yes 2= No	1=Green 2= Red 3= Non-specified	1 = Yes 2= No>> Q.17					

****
1= Do not know the effect of the red tube-well
2= Safe sources of green tube-wells are far away
3= Not possible to travel far away due to sickness
4= Refused to collect water from the neighbors
5= Poor relationship with the neighbor or egoistice behavior
6= Not one available to fetch the fresh water
7= The taste of water are good
8= The extent of sickness of the HH are so low
*9= Other * (Please specify-)*

Q 17. Where did you heard about arsenic poisoning?

Serial No.	Medium	Code (Serial)
1	DPHE survey	
2	DPHE card	
3	TV / Radio	
4	Newspaper	
5	Govt. Health worker	
6	NGO Worker	
7	School/College	
8	Others (Specify- ....)	

Q 18. Information on NGO Activities for Awareness Purpose

Is there any arsenic related NGO activity?	What type of awareness programs they have?	Have any HH member participated?
1 = Yes, 2= No	1 = Training 2 = Rally 3 = Group meeting 4 = Poster and flyer 5 = Others	1 = Yes 2= No

Q 19. Information on Social Stigma (only for women now residing with HH)

(I) Due to *Arsenicosis* Existence of Social Stigma Related to Marria

Member ID	Marital Status*			If Divorced or Separated then -		
	Code Below**	When did you marry?	Amount of Dowry Paid (In Tk.)	Year	Reasons are - 1 'Arsenicosis' 2 'Other'	

(II) Social Stigma due to *Arsenicosis* of the Affected HH

Member ID	What following types of stigma are you facing due to Arsenicosis? (Code below*)					

1 = Refused water collection from the neighbors
2 = Eligible persons are refused jobs
3 = The affected are avoided in social activities
4 = With advancement of the diseases, patients become unemployable
5 = Affected young women being compelled to stay unmarried ;
6 = Marry another due to presence of Arsenicosis in the body of first wife;
7 = Other

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