Impact of arsenic contamination in groundwater on poverty and choice of mitigation technology for rural communities in Bangladesh

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Abstract

Discovery of the presence of arsenic in the drinking water in Bangladesh has been a cause of red alert in the public health arena. With a per capita income of US$482 (2006), dealing with this crisis is a major challenge for the government of Bangladesh, donor communities and the NGOs working in Bangladesh. However, heterogeneity of the people in terms of their choices for mitigation measures, income/wealth, information, health, poverty, social status and religion, often makes it difficult to find an efficient solution.

The main focus of the study is to look into the current status of arsenic contamination in the rural drinking water sources in Bangladesh to a) understand the effect on the resource utilization pattern at the household and its consequence on poverty status of the household due to arsenic related risks; b) determine the preference in terms of mitigating measures at the household and at the community level; and c) analyze precautionary as well as preventive measures adopted at the household and at the community level in terms of income, wealth and community characteristics

The study finds that in terms of adoption, information and proper information provides a major role for adoption of technologies. It has also found that some technologies are more popular among educated groups compared to others.

It finds that higher O&M costs may deter poor households to adopt rainwater harvesting, arsenic and iron removal plant and tara pump technologies. At the same time, people who are using these technologies are willing to pay more for better quality of services, implying that current status of services are not satisfactory to many. People with lower literacy level prefers deep tubewells and tara pump technologies because they are mostly supplied through government institutions. Interestingly, income poverty is not a major deterrent for adoption of technologies because most of them are provided by the NGOs and Government Agencies. On the other hand asset poor household seem to prefer dug well and arsenic and iron removal plants. However, as people improves their wealth they would also, at the same time, will not use dug well for their source of water supply.

Media exposure is a very important variable to influence decisions related to adoption or rejection of technologies. Consequently, government should use appropriate messages on Radio, TV and Newspapers to influence the decisions. With the current strategy of communication that exists in Bangladesh media, households with media exposure do not like to use dug well, pond sand filter, and piped water supply technologies.

Providing information on arsenic mitigation technologies will significantly improve adoption of dug well, piped water supply system, rain water harvest system and arsenic and iron removal technologies. It is also a major variable to influence the decision at the household level. Interestingly, the current level of information on deep tubewell is working against this technology, mostly because of inefficiencies in providing the quality of service by the providers, despite the fact that this technology is the most poor-friendly technology.

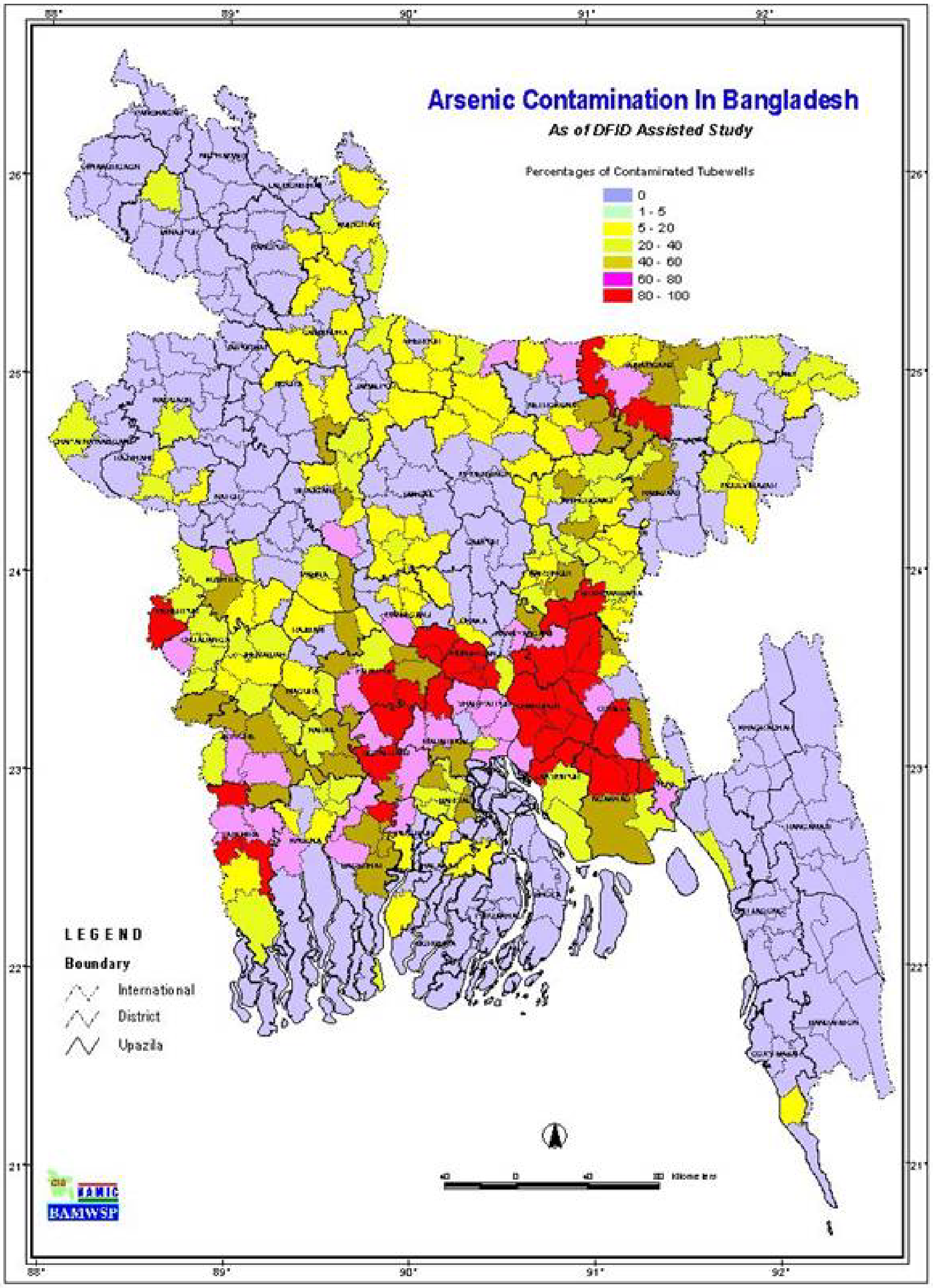
1.1 Introduction

Discovery of the presence of arsenic in the drinking water in Bangladesh has been a cause of red alert in the public health arena. With a per capita income of US$482 (BER, 2006), dealing with this crisis is a major challenge for the government of Bangladesh, donor communities and the NGOs working in Bangladesh. Ever since the discovery of arsenic in the drinking water in Bangladesh by WHO in 1993, the arsenic problem has been great challenge for social planner to bring the people out of danger creates from continuous drinking of arsenic contamination water. Policy makers, doctors, scientists, geologists, engineers are engaged to find out the feasible treatment options for the affected people and technologies to avert such a disaster. At the same time, policy makers are engaged in the debate to determine the best feasible option to reduce the risk.. Similarly, social workers and NGOs began activities to rehabilitate people, provide technological solutions at low cost and also made people aware against the disaster. However, heterogeneity of the people in terms of their choices for mitigation measures, income/wealth, information, health, poverty, social status and religion, often makes it difficult to find an efficient solution. It is, at the same time, important to know which particular technological solution is more desirable from the social point of view and which solution of least desirable so that the expenditure made by government, NGOs, and also others national and international agencies bring in a socially acceptable outcome and help the millions. This study seeks to answer these questions.

1.2 Background

According to Bangladesh Arsenic Mitigation and Water Supply Project (of the World Bank) out of 4 million tube-wells installed in Bangladesh, 1.2 million have been found contaminated with arsenic (www.**bamwsp**.org). Map 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 500 ppb or 50 μg/liter (World Bank, 2001). Estimates by the Bangladesh Arsenic Mitigation Water Supply Project, nearly 30 percent of all tube wells in 258 *upazillas* of Bangladesh have higher arsenic content than the prescribed safe limit. For Bangladesh, this means that an estimated 27 to 60% of the population is at risk from arsenic exposure (Smith, Lingas and Rahman, 2000). This is equivalent of 28-50 million people in Bangladesh and most of them live in rural areas.

Map 1: Arsenic Contamination in Bangladesh (2001)



Source: http://www.bamwsp.org/maps/maps.h5.jpg

According to Poverty Monitoring Survey, 40.9% of the total population in Bangladesh are poor using the Direct Calorie Intake (DCI) method which assumes a daily minimum food requirement equivalent to 2122 kilocalorie while in terms of per capita income of the poor household in rural Bangladesh it is Taka 18.5 or US$ 0.31 per day (PMS[1], 2004).

Ever since the discovery of arsenic in the ground water, government and NGOs have been working to contain the impact of natural disaster and one of the major problem is linked with financing the mitigating measures. According to the Implementation Plan for Arsenic Mitigation (2003, draft plan), people are expected to run their water supply systems on a cost sharing principles which stipulates that while the capital cost for such system is paid by the government, the operation and maintenance costs shall be borne by the local people or users. However, while adopting this principle in the maintaining piped water supply project in the rural area by Bangladesh Arsenic Mitigation Water Supply project (BAMWSP, LGRD Ministry) the study observed, "The estimate of value of 'Arsenic free' water out of the total value of piped water is found to be in the range of Tk 10 to 13 per month (for supply of 8 liters per day per person) and this is rather low in comparison with Operation and Monitoring (O and M) costs of Tk. 30 per month for the stand post and Tk 70 per month for the domestic connection and also of the average income of rural households." (Junaid, *et.al.* 2002).
In this situation, the policy makers are in a state of dilemma on how to address the problem the efficiently. There are several technological options available too. Each of them have differences in terms of its fixed and variable costs and also in terms of coverage area. Some of them are purely home-based technologies while others are community-based technologies. Since households do suffer from the effect of arsenic in water, there is a genuine willingness to pay for a 'safe' source of water. There are also differences in terms of their ability to pay by individual households.

Each of these has difference implication for public expenditure, community resources, and household assets. At the same time, a community level solution requires a greater degree of participation by all the beneficiary household and cooperation among them. This is a difficult 'commodity' in rural areas where income disparity may not be as great as in urban areas but differences based on social stratification are quite acute and engraved in our social mosaic in rural areas.

On the top of these, there are intra-household biases in terms of impact of arsenic contamination. For example, arsenicosis is likely to have a more significance consequence

[1] Poverty Monitoring Survey 2004, Economic Review 2006, Page 142

on the life of person who is physically weak, malnourished, and drinks more water than others. Therefore, finding one mitigation measure for all or 'one size fits all' type of approach will be very difficult to deal with this social, economic and health crisis.

In an earlier study Khan (2007) shows that the probability of suffering from melanosis (a primary variant of arsenicosis) increases by 23 in 1000 individuals who are taking water from red tubewells and not from green tubewells. The study also shows that poverty reduction decreases the probability of suffering from arsenic related diseases. Finally, this study also shows that the marginal willingness to pay for switching to safe drinking water source is at least 170 taka (or 2.85 US$) per person per year in rural areas.

Considering these, this study examines various technologies being used in rural areas to understand whether these technologies are a) excluding individuals due to economic hardship, b) discriminating poorer households. Furthermore, the study would like to find out whether households are adversely affected while adopting the technology, which is often supplied by Government or by the NGOs.

1.3 Technologies in use to mitigate arsenic contamination in water

A number of mitigation technologies are being explored in South Asia and also in Bangladesh by various agencies. Typically, these technologies are classified in two broad categories: a) community-based technologies and b) home-based technologies.

Community-based technologies involve treatment of contaminated water using a range of oxidization and sedimentation methods (i.e. pond sand filter, dug well sand filter, surface water based pipe line water supply etc.) or finding arsenic free water from source like deep aquifers and surface water. Community-based technologies could be designed to supply water at home using piped water supply system or to supply water at one or several common collection points.

Home-based technologies on installed within the premise of a house. Like community based solutions, these technologies area also capable of removing arsenic from contaminated water sources (within a certain level of contamination) or uses sources like deep aquifers or rain water to reduce exposure to arsenic.

Each set of technologies as well as individual technologies has its pros and cons in terms of costs of maintenance and operations, advantages, disadvantages etc. A brief description of technologies available in our study area and, hence, included in the analysis is provided below:

a. Dug well (DW)

Dug wells are the oldest method of groundwater withdrawal for water supply. The water from dug wells has been found to be relatively free from dissolved arsenic and iron, even in locations where tubewells are contaminated. Each community used to have a dug well in many parts of rural Bangladesh. However, over the past decades with introduction of hand tube wells, the importance of dug wells was lost and communities did not find interest to maintain these wells.

One of the advantages of this technology is, it takes a small surface area to be installed, and hence, installation cost goes down drastically. Major disadvantages are some places may not be suitable for construction of dug well due to soil condition and dug well water may need to be filtered for the purpose of decontamination of other bacteria.

b. Deep Tube Well

The other alternative for groundwater supply is the development of deep tube wells. The British Geological Survey (1998) found only two out of 280 tube wells below 200 m in Bangladesh to be contaminated with high levels of arsenic (WHO, 2000). Use of deep tube well has been suggested as a safe option in the face of arsenic contamination of groundwater in the country. This technology is costly and can be used when a large number of families or a community takes active interest to install and maintain them.

c. Pond Sand Filter (PSF)

This is a surface water based technology which purifies pond water using a filtration system designed to remove arsenic from water. Pond water is pumped to a storage unit first; after filtration hand pumps are used to extract water for drinking and cooking purposes. One PSF can supply the daily requirement of drinking and cooking water for about 40-60 families with a cost of about US$ 600. The greatest challenge for this option is to find suitable ponds which are permanently free from pisciculture and use of bathing and washing clothes, cattle, etc.

d. Piped Water Supply System

This is a community based drinking water technology. In this technique either surface water after filtering or ground water extracted from deep aquifer through pump is supplied to households through pipe line. One water point is installed for four five families. The long-term goal of Bangladesh Government is to introduce piped water supply systems both in the rural and urban areas preferably based on surface water treatment plants.

e. Rain Water Harvester (RWH)

Rainwater harvesting is basically a household-based technology. In an underground storage tank of capacity around 32,000 liter, rainwater is collected during rain season. Through hand pump, the rain water is extracted from the storage tank and is used throughout the year. Rainwater harvesting in parts of Bangladesh where rainfall is intense, seems to be the most viable source of drinking water supply. However, due to long term storage of water in the tank, there is high risk of water getting contaminated from other bacteria.

f. Arsenic and Iron Removal Plant

This technology has been provided in household basis by NGO Forum in our study area. The plant effectively removes arsenic and iron from ground water. Groundwater drawn by hand pump from tube-well has dropped into the aeration/ sedimentation chamber (around 1m diameter and 1m height, with cascades on top of this chamber for better aeration). This promotes oxidation of iron and arsenic by the air. This technology needs regular maintenance work. Filtration media is back-washed twice or thrice in a week depending on the rate of discharge through the 8 liter media, and sludge is collected in a holding pond.

g. Tara Pump

This hand pump is designed by UNICEF. These are designed for lifting water from bore-wells with static water level not exceeding 15m. It is used to extract water from near surface levels. This is a non-mechanical pump uses muscle power and has very little operating costs. Usefulness of tara pump in arsenic prone region depends on availability of arsenic free water in shallow aquifers. Table 1.1 presents a comparative picture of costs and coverage of these technologies in Bangladesh.

Table 1.1: Comparative Analysis of Costs and Capacity of Mitigating Technologies in Arsenic Prone Regions of Bangladesh

Technology Name	Fixed Cost (for 10-12 households capacity)** (Taka) [1 dollar = 68 taka]	Fixed costs* In Taka (for 100 households capacity)
Dug Well (DW)	30000-35000	127,000.00
Deepset Tube Well (DTW)	50000	1,460,148.00
Pond Sand Filter (PSF)	100000	1,748,900.00
Piped Water Supply System (PWSS)	150000-200000	1,200,400.00
Community based Rain Water Harvest System (CRWHS)	15000-20000	2,402,780.00 (with DTW)
Arsenic and Iron Removal Plant (AIRP)	40000-50000	541,688.00
Tara Pump (TP)	15000-20000	-

Source: * siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/ArsenicVolII_PaperIV.pdf. ** Data from NGOs delivering these technologies in Bangladesh.

1.2 Policy Relevance and Objective of this Research

The main focus of the study is to look into the current status of arsenic contamination in the rural drinking water sources in Bangladesh to:

- understand the effect on the resource utilization pattern at the household and its consequence on poverty status of the household due to arsenic related risks
- determine the preference in terms of mitigating measures at the household and at the community level.
- analyze precautionary as well as preventive measures adopted at the household and at the community level in terms of income, wealth and community characteristics
- estimate the resource needs both at the public and private level to achieve the Millennium Development Goal 7 related to access to safe drinking water in Bangladesh

This research would eventually help to

- design effective mitigation plan for communities with varying characteristics
- understand adoption of mitigation measures at community levels with respect to the incidence of poverty
- estimate costs of mitigation at the household level and at the community level.
- estimate resource needs to meet MDG objective of fulfilling Bangladesh's target to achieve the access to 'safe drinking' water to all by 2015.

2.0 Research Methods

The objective of the study is primarily linked with mitigating technologies being delivered to rural households in Bangladesh. Consequently, the sampling unit of this study is the technologies used by the households. In order to understand the adoption and non-adoption behavior, households within the command area of each of these sampling units were surveyed using a questionnaire. At the same time, institutional information were collected from the organizations (both government and non-government) delivering these technologies.

2.1 Survey set-up and sampling

The research has been carried out in severely arsenic prone rural areas in Bangladesh. Study sites were selected after studying available information about arsenic concentration levels, number of patients and GO/NGO intervention in different upazillas of Bangladesh. Some leading NGOs working for supplying alternative drinking water options have been contacted in October 2005. For site selection, we used the following criteria:

1. Percentage of tube wells are contaminated by arsenic (concentration level)
2. Number of patients per one thousand population

3. GO/NGO intervention[2]

List of all upazillas identified for having arsenic contaminated tube wells along with number of patient and GO/NGO intervention, has been collected from DPHE website. Median concentration level (20% of the tube wells affected by arsenic) has been selected as a cut off point. Upazillas having equal to or more than the median concentration level (50 upazillas) have been short listed at the first stage based on the concentration level.

In the second stage, number of patient in one thousand populations has been taken into account. Based on the distribution of the patient number in the short listed unions, third deciles (0.083 patients per one thousand populations) have been selected as a cut off point. In the second stage, we short listed thirty four upazillas.

In the third stage, GO/NGO intervention has been considered to obtain a shorter list of upazillas. As technological options/choice is one of the major focuses of the research, we wanted to have GO/NGO interventions to have wider set of technologies. Hence, same GO/NGO working in more than one upazilla has been discarded from the short list prepared at the second stage. We came up with a list of twelve upazillas having around fifteen different GO/NGO interventions.

In the fourth stage, these NGOs were contacted to obtain detailed information on technologies promoted in different upazialls. Based on their information, we selected five upazillas from five different districts and four (old) divisions of Bangladesh for final survey. Ten villages from three unions of Sharsha (Jessore), fifteen villages from two unions of Soanargaon (Narayanganj), eight villages from three unions of Babuganj (Barisal), five villages from two unions of Ghior (Manikganj) and nine villages from three unions of Hajiganj (Chandpur) were selected as they cover different arsenic prone parts of the country and also cover various arsenic mitigation technological options. All of our study sites are intervention areas of large scale GO/NGOs. Sharsha is the project area of Asia Arsenic Network (Jessore); NGO Forum is working in Manikganj and Babuganj in collaboration with their partner NGOs; BRAC has long experience in arsenic mitigation in Soanargaon (Narayanganj) and DPHE is working in Hajiganj (Chandpur). In these five Upazilas, villages were selected that met the criteria of having high arsenic contamination, where there is a drinking water problem due to arsenic, and either have external mitigation projects ongoing

[2] Intervention is defined as specific, regular, and systematic activities carried out by GO and NGOs to provide medical facilities to arsenic affected patients and to facilitate adopting household based and/or community based arsenic removal techniques.

or nothing at all. For details of our study area are seen is appendix. Lists of safe drinking water option technology user group committee leader's name and location were collected from GOs and NGOs. Our primary sampling unit was arsenic removal and arsenic free drinking water technology options provided by GO and NGOs in our study area. From the list we followed stratified sampling procedure based on technological options available to draw sample. We also selected ten villages from Sonargaon and Hajiganj as our non intervention area based on information collected from GOs and NGOs and field visits by researchers. A predetermined representative number of people from different technology users and people having no technological options were interviewed; mainly head of households (75%), of whom 95 percent are men. The distribution of our sample units across different upazillas and technologies is presented in Table 2.1.

To conduct interviews, a household survey questionnaire has been developed by the research team in mid November 2005. The survey questionnaire was finalized after two pretesting in Nilkanda village of Sonargaon and Putia village of Daudkandi. Eleven interviewers were hired based on educational qualification and previous work experience. These field interviewers were thoroughly trained and used for pretesting the questionnaire. Around 2000 face to face interviews were planned by field interviewers from second week of December 2005 till second week of January 2006 using household survey questionnaires. The questionnaire consists of five sections. Two general sections consisting of basic socio-economic and demographic and water demand related questions; three other sections were designed for households whose family members are affected by arsenicosis disease and for users of specific safe drinking water option technology (both household based and community based technology).

Based on the above sample plan, a total of 1966 households were surveyed using a detailed questionnaire from the command area of the AMTs being in use. However, our random sample shows that only 1385 of them used at least one of the arsenic removal technologies and the rest did not adopt any of these technologies even though they live in close proximity to the technology available in their community (Table 2.2).

Table 2.1: Sample Plan for intervention options

Name of Upazilla	Community-based Arsenic Mitigating Technologies								Total
	DW	PSF	PWSS	DTW	RWHS	AIRP	CRWHS	TP	
Shsrsha	17	6	1						24
Sonargaon	10			9			5		24
Ghior	2		1		6	10	5		24
Babuganj		4		20	22				46
Hajiganj		3		17				10	30
Total	29	13	2	46	28	10	10	10	148

NB: TP= Tara Pump; RWH=Rain Water Harvesting; DTW=Deep Tube Well; PSF=Pond Sand Filter; PWSS=Pipe line water supply system; DHTW=Deep hand tube well; DW=Dug Well; CRWH=Community Rain Water Harvesting; AIRP= Arsenic and Iron Removal Plant.

Table 2.2: Sample Households with adoption of arsenic removal technology

	Technology in use				
	No technology	Community Technology	Home Technology	Both Technology	Total
Sharsha		498	1	5	504
Sonargaon	475	88	34	4	601
Ghior	3	194	1	1	199
Hajiganj	98	235	3	1	337
Babuganj	5	320			325
Total	581	1335	39	11	1966

Source: Field Survey, 2006

In addition to the household survey, several semi-structural key informant interviews were carried out by the research team in the study area. Local primary school teachers, NGO staff, village elders and leaders, politicians, project users, etc were interviewed to have an in-depth overview of the case study areas. The research team also carried out 6 focus group discussions with men and women (separately and collectively) in each part of the study area. Overall, 29.6 percent of the households are either excluded or remained outside the influence of the technologies promoted by government, NGOs and other organization in these areas.

2.2 Household Profile of the Sample

Households surveyed using the questionnaires are initially examined in terms of their socio-economic and demographic profiles. Table 2.3 shows the profile of the head of the households surveyed in this study. Education is often correlated with the social status of a household. In rural Bangladesh most of the household have a high degree of illiteracy. The following table shows that most of the heads of the household are illiterate (69.5%). It is, therefore, highly likely that these households have a much lower income level. It represents the broad characteristics of the households in rural Bangladesh.

Table 2.3: Educational Profile of the Head of the Households

	Frequency	Percent
Illiterate	1367	69.5
Primary school (Class 1-5)	274	13.9
High school (Class 6-10)	167	8.5
SSC/Equal	83	4.2
HSC/Equal	41	2.1
Graduate	24	1.2
Postgraduate	5	0.3
Medical/Engineering	2	0.1
Diploma/Polytechnic	2	0.1
Others	1	0.1
Total	1966	100

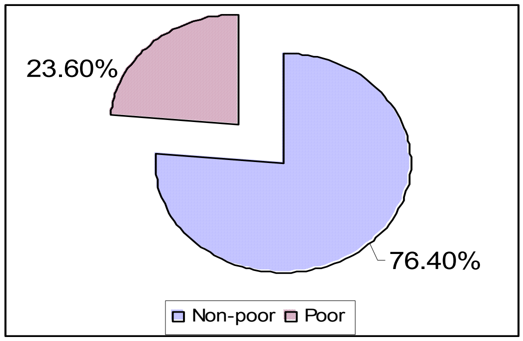
Source: Field Survey 2005-6

Education Status also provides an important proxy to determine the level of awareness about arsenic problems in the household. Since presence of arsenic cannot be determined using odor, color or taste, it is very difficult to convince people that the water from their tube-wells could be poisonous (due to arsenic contamination). Moreover, arsenic issue creates a further problem because of its long time lag between drinking of contaminated water and appearance of health effects.

Average annual household income is about eighty six thousand taka ($1324), while more than twenty percent of the households have an average annual income of twenty three thousands Taka ($387) which is substantially below the national average. Trimming off the 5 percent minimum and maximum values (to avoid presence of extreme income values in the sample), an average per capita income per month equals to Taka 1071 (US$16), which is slightly higher than the national rural per capita income per month. An average household consists of five family members, of which two works, usually men. The survey questions on income, related to the period of growing seasons within last 12 months. Hence the figures are only relevant for year 2005. Income of the household includes a variety of activities, from crop growing, livestock rearing to wage earned from day labor. Using the reported in income from the survey and the national income poverty line[3], it shows that only 23.6% of the sample are poor while the rest are in the non-poor categories..

[3] Bangladesh Economic Review 2006, Page 146

Figure 2.1: Distribution of the Surveyed Households



Source: Field Survey, 2005.

Occupation of the head of the households is often regarded an important variable that traces the level of information the household possess to deal with social or health crisis. The occupational distribution of the households is shown in Table 2.4. Table 2.4 shows that most households are agricultural households who are mainly dependent on crop production and livestock rearing. The sample in each category is divided using the income poverty line, and its shows that a much higher level poverty exists among the farming households.

Table 2.4: Professional criteria over the Poverty Status (%)

Professional Criteria	Poor	Non Poor
Farmer	33.4%	21.0%
Fisherman	0.2%	1.7%
Forestry & Livestock	0.0%	0.2%
Sales man	0.0%	0.3%
Trader	10.1%	15.7%
Transport worker	0.9%	1.5%
Salaried person	4.1%	13.6%
Professional	0.6%	1.3%
Day laborer	4.1%	3.0%
Others	46.6%	41.7%
Total	100.0%	100.0%

Source: Field Survey, 2005.

House type, wall materials, source of energy used and latrine types often illustrates the standard of living of a household. Table 2.5 shows that among our sample only 18.5% had brick walls, .5 percent are electrified, and nearly 40% has sanitary latrine. This shows that even the non-poor households in rural areas are not very rich in the usual sense.

Table 2.5: Housing Characteristics of the Households

Wall Material	Percent	Source of Energy	Percent	Type of Latrine	Percent
Brick/Cement	18.5	Electricity	0.5	Sanitary	39.7
Mud brick	10.9	Gas	4.1	Ring/slap	45.9
Tin	62	Kerosene	0.5	Kacha	12.1
Wood	1.3	Batteries	0.2	Open field/river	1.7
Hemp/Hay/Bamboo	6.8	Wood/Coal	39.8	Others	0.6
Others	0.5	leafs/cow dung/straw	54.6		
		Others	0.3		
Total	100	Total	100	Total	100

Source: Field Survey 2005.

Table 2.6 shows that more than 50% of the households never read newspapers, nearly 34.5 percent never listened to radio and nearly 20.8 percent never watched TV. It reveals the weakness of traditional media (print and electronic) to reach out to the rural population.

Table 2.6: Media Exposure

Read/Listen/Watch	Newspaper	Radio	TV
Never	52.3	34.5	20.8
Once in a month	1.2	0.8	0.8
Once in a week	2.9	2	4.9
Daily	15.9	26.4	45.6
Very irregularly	26.5	35.8	27.4
Others	1.2	0.5	0.5
Total	100	100	100

Source: Field Survey 2005.

2.3 Arsenic-effect at the household level and mitigating options

According to the Table 2.7 11.6% percent households reported on the existence of arsenic patient in their family and of which, 4.4 percent informed that at least one member is affected in their household. Besides,

Table 2.7: Number of family member(s) affected by arsenic

Number of family member(s) affected	Percent of total household	Percent of affected household
1 member affected	4.4%	100.0%
2 members affected	2.6%	58.1%
3 members affected	1.9%	41.9%
4 members affected	1.5%	32.6%
5 members affected	1.2%	26.3%
Total	11.6 %	
AVERAGE NUMBER OF AFFECTED		**1.16**

Source: Field Survey 2005.

The highest 5 members are also affected in 1.2 percent households. It reflects the diverse distribution of the affected households. At the same time, Table 2.8 shows that of the affected people only 28 percent received some sort of treatment to deal with diseases related to arsenic poisoning while the rest did not go for treatment. Of the rest, who do not take treatment, nearly 34 percent are not even aware of the disease, 37 percent are aware but they do not consider the diseases severe enough to be treated, and 4.5 percent find it difficult to afford.

Table 2.8: Information of Arsenic affected people

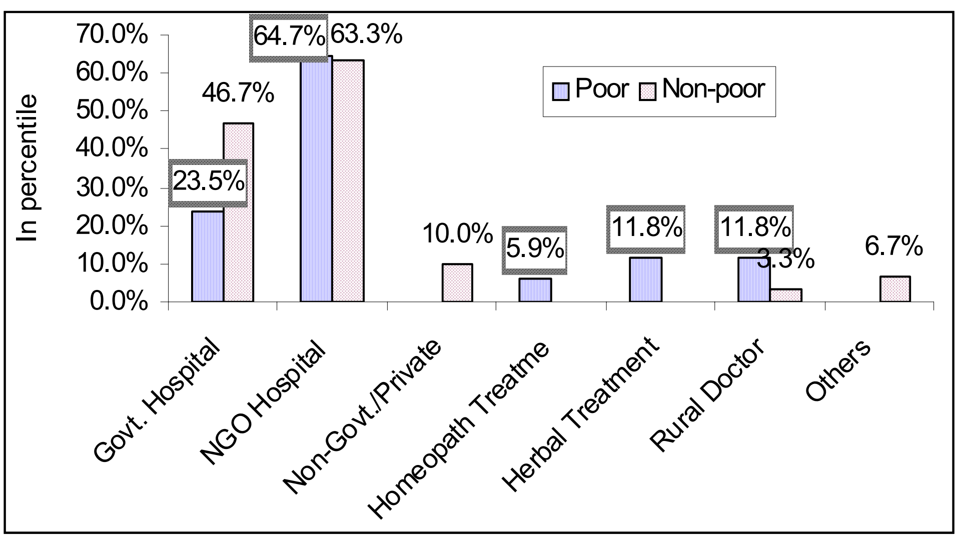
Description	Percent
Treatment received	27.91
Reasons for not receiving treatment (%)	
Shortage of Money	14.5
Diseases is not severe	37.1
Hospital not nearest place	8.1
Not aware reason of disease	33.9
Others	6.5

Source: Field Survey 2005

2.4 Access to healthcare facilities

Among the affected households who received treatment only 23.5 percent received it from government hospitals of them 46.7 percent are non-poor households. Under this situation, the highest 64.7 percent arsenic affected poor household took treatment facilities from NGO hospitals and the almost equal i.e. 63.3 percent non-poor also enjoyed the treatment provided by NGO hospitals. As a least cost option, arsenic affected poor household also adopted homeopath, herbal and rural doctors' treatments.

Figure 2.2 : Choices of different health services/ treatment providing agencies



Source: Field Survey, 2005

3.0 Choice of Arsenic Mitigating Technologies (AMTs)

The study area selected to carry out the comparative analysis of choice of mitigation techniques, are three severely arsenic contaminated upzillas of Bangladesh with highest level of intervention done by two leading NGOs. Asia Arsenic Network (AAN), under the JICA Partnership Program, have been working in Sharsha Upazilla of Jessore district to promote various arsenic free and arsenic removal technologies. The nature of intervention in Sharsha is intensive and in-depth. Generally majority 90% of the costs (setup and maintenance) are borne by the AAN and 10% by the user group.

NGO Forum is a national apex networking service delivery organization in the water supply and sanitation sector dedicated to contribute in the improvement of the public health status of the poor and disadvantaged people of Bangladesh. In collaboration with partner NGOs' they have been working in all 64 districts and in about 14,640 villages in Bangladesh. The NGO Forum has their work distributed in all over Bangladesh but Babuganj Upazilla of Barishal and Ghior Upazilla of Manikganj, they provided several different household as well as community based AMTs. The water supply technologies are provided maintaining a 90:10 cost sharing approach in line with the National Policy for Safe Water Supply and Sanitation. It is, however, important to note that effectiveness of these technologies depends on the level of arsenic in the water. At the same time, adoption of any or all of these technologies are affected by economic factors like annual operating costs, installation costs, level of awareness among the people, etc., as well as by availability of support services from government and non-government institutions. Consequently, none of the technologies are ranked in any order.

3.1 Community Based Mitigating Technology and Poverty

Choices of different community based mitigating technologies are already identified during survey and according to the following Table 3.1, poor and non-poor of all surveyed Thana are indifferent to choose the Dug Well, except Bauganj Thana the poor choose most the Deep Tube Well and it may be due to coverage and availability as well as more user friendly. In case sof using PSF, poor choose more in Sharsha Thana but, non-poor choose most in Hajiganj and Babuganj and this is also due to accessibility. The reverse scenarion in choice of PWSS is also shown in Sharsha and Ghior Thana and AAN working in Sharsha concentrated more on coverage especially to poor, but in case of Ghior NGO Forum for drinking water has provided this technology based on the willingness to pay of the users and it ultimately provided more access to non-poor. In case of CRWHS, it is limited to coverage as it is costlier and subject to the availability of rain but poor chose more due to almost ‘zero’ maintenance cost.

Table 3.1: Distribution of choices of technology among poor and non-poor affected households

	Dug Well		Deep Tube Wells		Pond Sand Filter		Piped Water Supply System		Community based Rainwater Harvesting system		Arsenic and Iron Removal Plant		Tara Pump	
	POOR	NON POOR	POOR	NON POOR	POOR	NON POOR	POOR	NON POOR	POOR	NON POOR	POOR	NON POOR	POOR	NON POOR
Sharsha	79.3%	72.9%			91.3%	62.2%	84.6%	59.5%						
Sonargaon	13.8%	13.3%	14.9%	10.6%					16.7%	7.0%				
Ghior	5.7%	7.9%					15.4%	38.8%	66.7%	54.4%	100%	97.1%		
Hajiganj			58.1%	26.3%	1.4%	4.8%							100%	95.8%
Babuganj			27.0%	59.2%	7.2%	31.9%								

Source: Field Survey 2005.

In case of AIRP and TP the difference in choice between poor and non-poor is almost insignificant as these are supply driven and new technology to introduce and it needs motivation and easy access

3.2 Difference in Mitigating Technologies between poor and non-poor

a. Investment/One time fixed cost

Figure 3.1 shows the costs incurred by poor and non-poor households while setting up different mitigating technologies. It shows that for Tara Pump, there exists a significant difference in terms of the amount of initial contribution made by poor and non-poor households. Non-poor households seem to significantly higher amount as one time cost compared to poor households. Table 3.2 illustrates the numbers. It shows comparatively AIRP, PSF, DTW, CRWHS and TP technologies are more costly in terms of initial costs for the poor households. Consequently, poor households might not be able to pay for these technologies if the provision for payment is mandatory.

Table 3.2: Costs of AMTs by Poor and Non Poor Households

	ANNUAL COSTS		ONE TIME COSTS	
	POOR	NONPOOR	POOR	NONPOOR
DW	97.85	119.16	875.00	678.57
DTW	-	5,344.00	1,337.92	1,340.15
PSF	95.45	198.52	1,200.00	1,201.25
PWSS	347.63	219.59	433.33	849.26
CRWHS	180.00	195.75	1,100.00	1,603.23
AIRP	-	300.00	1,800.00	1,273.08
TP			625.00	6,000.00

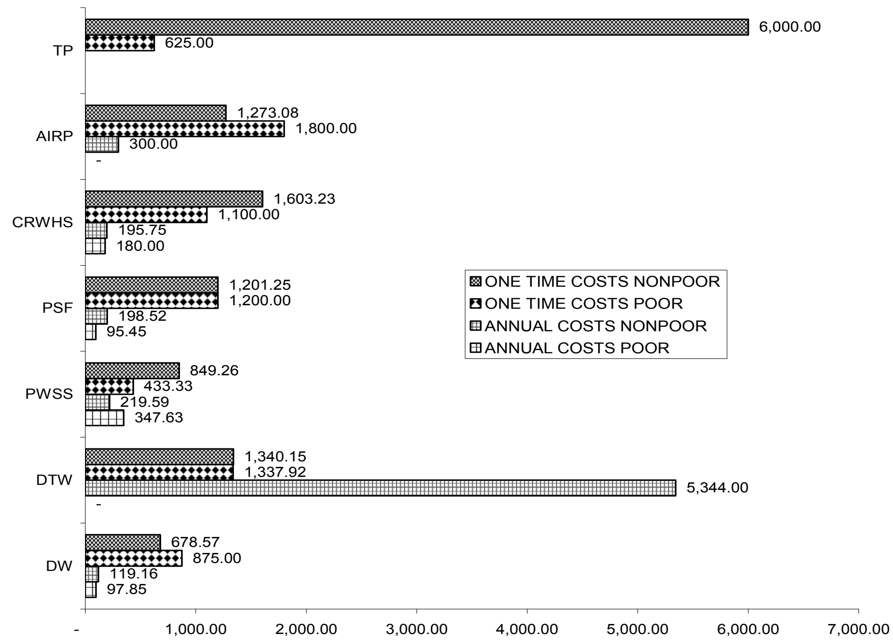
Source: Field Survey 2005.

For DW, and AIRP, poor households are paying even more than the non-poor households. At the same time, for DTW there is an annual costs and poor households are exempt from paying any annual fees. This is also true for AIRP, and TP technologies.

b. Maintenance cost

Table 3.2 and Figure 3.1 further shows that besides the initial one time costs, there are maintenance costs for each of these technologies. Table 3.2 shows that there are differences in terms of the rate of payment of annual fees for poor and non-poor households while for DTW the annual maintenance costs are significantly higher than other technologies. At the same time it shows that poor pays higher costs in terms of PWSS than the non-poor households.

Figure 3.1: Difference in incurred costs of technologies by poor and non-poor



Source: Field Survey 2005.

Field Data shows that one time costs for adoption of technology is about 4.92 percent of the income of the poor and 1.18% of the income of the non poor household. At the time, the annual maintenance cost is about 0.67% of the income of the poor (annual income) while it is only 0.23% of the income of the non-poor household. Clearly, poor households are paying a higher proportion of their income to finance AMTs. Consequently, it is important to know whether these technologies have any significant biases for poor and non-poor households. Furthermore, we would like to know how households usually pay for these costs.

4.0 Factors affecting adoption of AMTs

While several agencies have been working in various locations in Bangladesh to promote AMTs for the communities, this study shows that nearly 29.6% of the population remained outside and have not been using the technology. In terms of the factors influencing the decision to adopt such technologies, major factors include: a) Initial costs, b) one time costs, c) educational status at the household level, d) income level, e) wealth, and f) media exposure and g) awareness on AMTs. It is expected that individuals awareness level, income, wealth and education would change the probability of adoption of AMTs. In total, 1379 households adopted at least one of the community-based AMTs in our sample. A probit analysis[4] on choice of technologies were used to determine the degree of influence that these variables have on adoption behavior. Table 4.1(a through g) shows the STATA results. Based on these tables, we can deduce the following:

4.1.1. Adoption of Dug Well Technology as AMTs

Twenty one percent of the households seem to be using this technologies in our sample. The probit model on adoption of DW Technology suggests:

- Adoption of DW technology is independent of income and O&M costs. In fact, there is very little O&M costs for technology.
- Probability of adoption of decreases by .03 with each 1000 taka increase in installation costs.
- Probability of adoption of DW technology decreases by 0.017 with increase in educational level by 1 level – 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary.
- Probability of adoption of DW technology 0.0018 percent with increase in the wealth index by 1 unit.
- Probability decreases 0.047 with media exposure – meaning that people with media exposure are aware of better technologies or represent a higher level wealth class.
- Probability increases by 0.09 with increase in the level of technological awareness.

Overall, DW technology is not liked by people who avoids physical labor and are in a higher social strata.

[4] Since technologies are not ordered, a multi-nomial logit analysis is not appropriate. At the same time, scientific literature suggests under some circumstances all the technologies are efficient in removing arsenic (Ahmed, 2001). Since, each of these technologies are propagated by some institutions (government and non-government) in rural Bangladesh, we had assumed that the technologies are effective given the level of arsenic in the water in that area.

Table 4.1.a: Adoption of Dug Well Technology – Probit Analysis

```
.probit dw ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -710.61005
…..
Iteration 5:   log likelihood = -650.66868

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =     119.88
                                                  Prob > chi2     =     0.0000
Log likelihood = -650.66868                       Pseudo R2       =     0.0844

------------------------------------------------------------------------------
          dw |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ctaka1 |  -.0000322   .0000805    -0.40   0.689      -.00019    .0001256
      ctaka2 |  -.0005177   .0001358    -3.81   0.000    -.0007838   -.0002516
      edumax |  -.0667654   .0183899    -3.63   0.000    -.1028089   -.0307218
     pcincom |   1.21e-06   .0000144     0.08   0.933     -.000027    .0000294
      windex |  -.0069059   .0026346    -2.62   0.009    -.0120696   -.0017422
       media |  -.1766773    .090846    -1.94   0.052    -.3547322    .0013776
       AMTs  |   .3649246   .0830512     4.39   0.000     .2021472    .5277021
       _cons |  -.3888731   .1089718    -3.57   0.000    -.6024539   -.1752922
------------------------------------------------------------------------------

. dprobit dw ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -710.61005
… …
Iteration 5:   log likelihood = -650.66868

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    = 119.88
                                                        Prob > chi2   = 0.0000
Log likelihood = -650.66868                             Pseudo R2     = 0.0844

------------------------------------------------------------------------------
      dw |      dF/dx   Std. Err.      z    P>|z|     x-bar  [    95% C.I.   ]
---------+--------------------------------------------------------------------
  ctaka1 |  -8.49e-06   .0000212    -0.40   0.689   87.2335   -.00005  .000033
  ctaka2 |  -.0001365   .0000339    -3.81   0.000   225.225  -.000203  -.00007
  edumax |  -.0176006   .0048447    -3.63   0.000    3.4409  -.027096 -.008105
 pcincom |   3.20e-07   3.79e-06     0.08   0.933   1480.63  -7.1e-06  7.7e-06
  windex |  -.0018205    .000694    -2.62   0.009   40.0654  -.003181  -.00046
   media*|   -.047195   .0246168    -1.94   0.052   .584482  -.095443  .001053
   AMTs *|   .0940775   .0209381     4.39   0.000   .564177    .05304  .135116
---------+--------------------------------------------------------------------
  obs. P |   .2110225
 pred. P |   .1813345  (at x-bar)
------------------------------------------------------------------------------
(*) dF/dx is for discrete change of dummy variable from 0 to 1
    z and P>|z| are the test of the underlying coefficient being 0

.

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs - ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs - MEASURED IN TAKA
edumax = highest educational attainment in the household
       0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income - MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media  =  Level  of  media  awareness  (0=none,1  =  at  least  exposed  to  TV/Radio
/Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).
```

4.1.2 Adoption of Deep Tube Well (DTW) technology

Thirty percent of the households seem to be using this technology in our sample. The probit model on adoption of DTW Technology suggests:

- Adoption of DTW technology is independent of income, O&M costs as well as wealth status of the household. This is provided mostly by the Department of Public Health Engineering (DPHE) of the Government of Bangladesh. Hence, it seem to be not at all influenced by income level and wealth status. The operation and maintenance cost is also seem to not linked to the choice.
- Probability of adoption of decreases by .004 percent with each 1000 taka increase in installation costs. Which means, the adoption behavior is not significantly influenced by the amount of installation costs (as the bulk of the cost is borne by the providers).
- Probability of adoption of DTW technology increases by 0.11 with increase in educational level by 1 level – 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary.
- Probability increases by 0.117 with media exposure – meaning that people with media exposure are likely to adopt this technology quicker than people with nos media exposure.
- Probability decreases by 0.28 with increase in the level of technological awareness. This is a puzzle for us. It is expected that DTW technologies provides arsenic free water to the households and yet we have observed that people with claims that they have knowledge on technology are not favoring adoption of DTW. One likely reason for this is that the knowledge on technologies might need qualifiers. It is possible that some people are only know 1 or 2 technologies rather than all technologies and we have observed that not all thanas have DTW technologies. However, probit estimates using a restricted sample (in two thanas where DTW were used) also gives a similar result. This means that people claiming to be aware of the technologies are not fully aware of the merit of this technology.

Overall, DTW technology is one the technologies being pushed by the government departments. However, it is a costliest technology in the list (see Table 4.1).

Table 4.1.b: Adoption of Deep Tube Well Technology – Probit Analysis

```
. probit dtw ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -846.82417
… …
Iteration 3:   log likelihood = -718.94256

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =     255.76
                                                  Prob > chi2     =     0.0000
Log likelihood = -718.94256                       Pseudo R2       =     0.1510
```

dtw	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ctaka1	-.0000193	.0000411	-0.47	0.639	-.0000998	.0000613
ctaka2	.000143	.0000524	2.73	0.006	.0000402	.0002457
edumax	.1105755	.0147573	7.49	0.000	.0816518	.1394992
pcincom	-.0000124	.000013	-0.96	0.339	-.0000378	.000013
windex	.0034948	.0023529	1.49	0.137	-.0011168	.0081064
media	.3628284	.0892497	4.07	0.000	.1879021	.5377546
AMTs	-.8453868	.0777756	-10.87	0.000	-.9978241	-.6929494
_cons	-.8801146	.1048798	-8.39	0.000	-1.085675	-.674554

```
. dprobit dtw ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -846.82417
… …
Iteration 3:   log likelihood = -718.94256

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    = 255.76
                                                        Prob > chi2   = 0.0000
Log likelihood = -718.94256                             Pseudo R2     = 0.1510
```

dtw	dF/dx	Std. Err.	z	P>|z|	x-bar	[95% C.I.	]
ctaka1	-6.37e-06	.0000136	-0.47	0.639	87.2335	-.000033	.00002
ctaka2	.0000473	.0000174	2.73	0.006	225.225	.000013	.000081
edumax	.0365721	.0048807	7.49	0.000	3.4409	.027006	.046138
pcincom	-4.10e-06	4.29e-06	-0.96	0.339	1480.63	-.000013	4.3e-06
windex	.0011559	.0007772	1.49	0.137	40.0654	-.000367	.002679
media*	.1173383	.0279432	4.07	0.000	.584482	.062571	.172106
AMTs*	-.2828014	.0251704	-10.87	0.000	.564177	-.332134	-.233468
obs. P	.3038434						
pred. P	.2701594	(at x-bar)					

(*) dF/dx is for discrete change of dummy variable from 0 to 1
z and P>|z| are the test of the underlying coefficient being 0

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs – ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs – MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income – MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

4.1.3 Adoption of Pond Sand Filter (PSF) Technology

Nearly 19 percent of the households seem to be using this technology in our sample. The probit model on adoption of PSF Technology suggests:

- Adoption of PSF technology is independent of income, O&M costs as well as awareness on AMTs at the household level. Several NGOs provided PSF technology to communities in rural Bangladesh.
- Probability of adoption of decreases by .002 per 1000 taka increase in installation costs.
- Probability of adoption of PSF technology decrease by 0.002 for each level rise in educational attainment. Educational level is measured as 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary.
- Probability increases by 0.0014 for each point rise in the wealth index. Meaning, richer household have a higher probability of adopting PSF technology than others.
- Probability decreases by 0.135 with media exposure – meaning that people with media exposure are not likely to adopt this technology than people with no media exposure. This is likely due to the fact, that they would prefer other more convenient technologies that this.
- Probability of adoption increase by 0.0158 for households with level of awareness on AMTs.

Overall, PSF technology is being pushed by NGOs in some parts of the country. Field data suggest that households (poor and non-poor) pays very similar amount of fee for connecting to this technology (see Table 4.1).

Table 4.1.c: Adoption of Pond Sand Filter Technology – Probit Analysis

```
. probit psf ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -664.64889
… … …
Iteration 4:   log likelihood =  -625.2769

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =      78.74
                                                  Prob > chi2     =     0.0000
Log likelihood =  -625.2769                       Pseudo R2       =     0.0592
```

psf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ctaka1	.0000244	.0000443	0.55	0.582	-.0000625	.0001113
ctaka2	-.0003037	.0000986	-3.08	0.002	-.0004969	-.0001105
edumax	-.0650986	.0187835	-3.47	0.001	-.1019136	-.0282836
pcincom	2.72e-06	.0000132	0.21	0.837	-.0000232	.0000287
windex	.0054557	.0026266	2.08	0.038	.0003077	.0106037
media	-.5166459	.0932383	-5.54	0.000	-.6993895	-.3339023
AMTs	.0629678	.0829218	0.76	0.448	-.0995559	.2254915
_cons	-.6193423	.1104687	-5.61	0.000	-.8358569	-.4028276

```
. dprobit psf ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -664.64889
… … …
Iteration 4:   log likelihood =  -625.2769

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    =  78.74
                                                        Prob > chi2   = 0.0000
Log likelihood =  -625.2769                             Pseudo R2     = 0.0592
```

psf	dF/dx	Std. Err.	z	P>|z|	x-bar	[95% C.I.	]
ctaka1	6.18e-06	.0000112	0.55	0.582	87.2335	-.000016	.000028
ctaka2	-.0000769	.0000245	-3.08	0.002	225.225	-.000125	-.000029
edumax	-.0164848	.0047268	-3.47	0.001	3.4409	-.025749	-.00722
pcincom	6.90e-07	3.35e-06	0.21	0.837	1480.63	-5.9e-06	7.3e-06
windex	.0013815	.0006631	2.08	0.038	40.0654	.000082	.002681
media*	-.1359911	.0252013	-5.54	0.000	.584482	-.185385	-.086597
AMTs *	.0158835	.0208486	0.76	0.448	.564177	-.024979	.056746
obs. P	.1870921						
pred. P	.1701826	(at x-bar)					

(*) dF/dx is for discrete change of dummy variable from 0 to 1
z and P>|z| are the test of the underlying coefficient being 0

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs – ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs – MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income – MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

4.1.4 Adoption of Piped Water Supply System (PWSS)

Nearly 11.5 percent of the households seem to be using this technology in our sample. The probit model on adoption of PWSS Technology suggests:

- Adoption of PWSS technology is independent of income, installation costs as well as wealth status. This seems to suggest that it is mostly availability that dictates adoptability of this technology.
- Probability of adoption of increase by .009 per 100 taka increase in the O&M costs (annual) of PWSS. This may be counter intuitive but in rural Bangladesh PWSS provided by the NGOs is no match for comparison with urban WSS. Each household is only given one tap outlet to collect water. Hence, households are willing to pay higher amount for more connections which is reflected in their willingness to pay for O&M charges. Nonetheless the changes in the adoption probability is very low.
- Probability of adoption of PWSS technology decrease by 0.014 for each level rise in educational attainment. Educational level is measured as 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary. This is also a puzzle but it is probability linked with the quality of water supply system.
- Probability decreases by 0.033 with media exposure – meaning that people with media exposure are not likely to adopt this technology than people with no media exposure. This is also linked with the quality of services provided by the water providers and hence they show their unwillingness to continue with this services at this quality.
- Probability of adoption increase by 0.068 for households with level of awareness on AMTs.

Overall, PWSS technology is provided by NGOs and also by LGIs. Table 3.2 shows that poor share much lower amount of costs compared to rich and it is also found to be non discriminatory with respect to rich and poor households implying that once the services is ready it is available to both poor and rich households and the current cost sharing principle is not discriminating rich or poor households.

Table 4.1.d: Adoption of Piped Water Supply System Technology – Probit Analysis

```
. probit pwss ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -492.93278
… …
Iteration 3:   log likelihood = -465.78129

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =      54.30
                                                  Prob > chi2     =     0.0000
Log likelihood = -465.78129                       Pseudo R2       =     0.0551
```

pwss	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ctaka1	.0000929	.0000393	2.37	0.018	.000016	.0001699
ctaka2	.0000349	.000071	0.49	0.623	-.0001043	.000174
edumax	-.0832897	.0234563	-3.55	0.000	-.1292632	-.0373163
pcincom	.000012	.0000118	1.01	0.311	-.0000112	.0000352
windex	-.0015733	.003	-0.52	0.600	-.0074532	.0043065
media	-.1838049	.1050837	-1.75	0.080	-.3897652	.0221553
AMTs	.3940536	.0969628	4.06	0.000	.20401	.5840972
_cons	-1.068843	.1270081	-8.42	0.000	-1.317775	-.8199119

```
. dprobit pwss ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -492.93278
… …
Iteration 3:   log likelihood = -465.78129

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    =  54.30
                                                        Prob > chi2   = 0.0000
Log likelihood = -465.78129                             Pseudo R2     = 0.0551
```

pwss	dF/dx	Std. Err.	z	P>|z|	x-bar	[95%	C.I.]
ctaka1	.0000166	7.01e-06	2.37	0.018	87.2335	2.8e-06	.00003
ctaka2	6.21e-06	.0000126	0.49	0.623	225.225	-.000019	.000031
edumax	-.0148366	.0040746	-3.55	0.000	3.4409	-.022823	-.006851
pcincom	2.14e-06	2.11e-06	1.01	0.311	1480.63	-2.0e-06	6.3e-06
windex	-.0002803	.0005343	-0.52	0.600	40.0654	-.001328	.000767
media*	-.0334166	.0195326	-1.75	0.080	.584482	-.0717	.004867
AMTs*	.068248	.0161822	4.06	0.000	.564177	.036531	.099965
obs. P	.1153009						
pred. P	.1020653	(at x-bar)					

(*) dF/dx is for discrete change of dummy variable from 0 to 1
z and P>|z| are the test of the underlying coefficient being 0

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs – ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs – MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income – MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

4.1.5 Adoption of Community based rainwater harvest system (CRWHS)

Only 4.5 percent of the households in our sample are using this technology. The probit model on adoption of CRWHS technology suggests:

- Adoption of CRWHS is independent of asset status of the household and media exposure.
- Probability of adopting CRWHS decreases by 0.25 with 1000 taka increase in the cost of O&M.
- Probability of adopting CRWHS increases by only 0.013 with increase in installation costs by 1000 a year. Increase in cost of installation symbolizes a better quality of water collection services and therefore, households are willing to pay more. But the increase in the degree of adoption is very low.
- Probability of adoption of CRWHS technology decrease by 0.0033 for each level rise in educational attainment. Educational level is measured as 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary. This means that educated family prefers other technology than CRWHS.
- Probability increases by .009 with increase in per capita income by 1, 00,000 taka.
- Probability of adoption increase by 0.015 for households with level of awareness on AMTs.

Overall, CRWHS technology is a tricky technology because it requires alternative source of water during the dry months of the year. In many cases it is linked with other water sources for running the dry months of the year. Consequently, not many people have adopted it.

Table 4.1.e: Adoption of Community Based Rain Water Harvest System Technology – Probit Analysis

```
. probit crwhs ctaka1 ctaka2 edumax  pcincom windex media AMTs
Iteration 0:   log likelihood = -252.90759
… …
Iteration 6:   log likelihood = -216.79598

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =      72.22
                                                  Prob > chi2     =     0.0000
Log likelihood = -216.79598                       Pseudo R2       =     0.1428
```

crwhs	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ctaka1	-.0060522	.0013976	-4.33	0.000	-.0087915	-.003313
ctaka2	.000318	.0000611	5.20	0.000	.0001982	.0004378
edumax	-.0830292	.0307358	-2.70	0.007	-.1432703	-.0227882
pcincom	.0000232	.0000123	1.89	0.059	-9.11e-07	.0000473
windex	.0018601	.0039924	0.47	0.641	-.0059649	.0096851
media	.1890632	.1636419	1.16	0.248	-.1316691	.5097955
AMTs	.3844587	.1391325	2.76	0.006	.1117639	.6571534
_cons	-1.829123	.1916143	-9.55	0.000	-2.20468	-1.453566

```
note: 6 failures and 0 successes completely determined.

. dprobit crwhs ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood = -252.90759
… …
Iteration 6:   log likelihood = -216.79598

Probit estimates                                       Number of obs =   1379
                                                       LR chi2(7)    =  72.22
                                                       Prob > chi2   = 0.0000
Log likelihood = -216.79598                            Pseudo R2     = 0.1428
```

crwhs	dF/dx	Std. Err.	z	P>|z|	x-bar	[95%	C.I.]
ctaka1	-.0002472	.0000378	-4.33	0.000	87.2335	-.000321	-.000173
ctaka2	.000013	3.78e-06	5.20	0.000	225.225	5.6e-06	.00002
edumax	-.0033917	.0013266	-2.70	0.007	3.4409	-.005992	-.000792
pcincom	9.47e-07	5.34e-07	1.89	0.059	1480.63	-1.0e-07	2.0e-06
windex	.000076	.0001637	0.47	0.641	40.0654	-.000245	.000397
media*	.0075037	.0066603	1.16	0.248	.584482	-.00555	.020558
AMTs*	.0152303	.0058306	2.76	0.006	.564177	.003802	.026658
obs. P	.0449601						
pred. P	.0163844	(at x-bar)					

```
(*) dF/dx is for discrete change of dummy variable from 0 to 1
    z and P>|z| are the test of the underlying coefficient being 0
```

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs – ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs – MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income – MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

4.1.6 Adoption of Arsenic and Iron Removal Plant (AIRP)

While UNICEF was working on iron removal plants for rural households in Bangladesh, they also discovered that the same plant could be altered to make it a arsenic removal plant too. Overall 5% of our sample households have been using this.

- Adoption of AIRP is not related to income level of the household.
- Probability of adoption, however, decreases by 0.25 for 1000 taka increase in annual O&M costs.
- Probability of adoption AIRP technology, however, increases by only 4.87×10^{-3} for each 1000 taka increase in the installation charge per household.
- Probability of adoption of AIRP technology decrease by 0.0018 for each level rise in educational attainment. Educational level is measured as 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary. This is also a puzzle but it is probability linked with the quality of water supply system.
- Probability also decreases by .0002 with increase in the asset status of the household by one point.
- Probability increases by 0.0147 with media exposure – meaning that people with media exposure are not likely to adopt this technology than people with no media exposure.
- Probability of adoption increase by 0.013 for households with level of awareness on AMTs.

Overall, AIRP technology is provided by NGOs in rural Bangladesh.

Table 4.1.f: Adoption of AIRP Technology – Probit Analysis

```
. probit airp ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood =  -291.2944
… …
Iteration 7:   log likelihood = -242.33176

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =      97.93
                                                  Prob > chi2     =     0.0000
Log likelihood = -242.33176                       Pseudo R2       =     0.1681
```

airp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ctaka1	-.0101009	.0018119	-5.57	0.000	-.0136521	-.0065498
ctaka2	.0001894	.0000669	2.83	0.005	.0000582	.0003206
edumax	-.0737875	.0284646	-2.59	0.010	-.1295771	-.0179979
pcincom	6.65e-07	.000019	0.03	0.972	-.0000367	.000038
windex	-.0091324	.0039564	-2.31	0.021	-.0168869	-.0013779
media	.603561	.1644424	3.67	0.000	.2812599	.9258621
AMTs	.5267416	.133857	3.94	0.000	.2643867	.7890964
_cons	-1.534519	.1866284	-8.22	0.000	-1.900304	-1.168734

```
note: 6 failures and 0 successes completely determined.

. dprobit airp ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood =  -291.2944
… …
Iteration 7:   log likelihood = -242.33176

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    =  97.93
                                                        Prob > chi2   = 0.0000
Log likelihood = -242.33176                             Pseudo R2     = 0.1681
```

airp	dF/dx	Std. Err.	z	P>|z|	x-bar	[95%	C.I.]
ctaka1	-.0002596	.0000554	-5.57	0.000	87.2335	-.000368	-.000151
ctaka2	4.87e-06	2.39e-06	2.83	0.005	225.225	1.9e-07	9.5e-06
edumax	-.0018967	.0009053	-2.59	0.010	3.4409	-.003671	-.000122
pcincom	1.71e-08	4.90e-07	0.03	0.972	1480.63	-9.4e-07	9.8e-07
windex	-.0002347	.0001263	-2.31	0.021	40.0654	-.000482	.000013
media*	.0147378	.0062885	3.67	0.000	.584482	.002413	.027063
AMTs *	.0131737	.005044	3.94	0.000	.564177	.003288	.02306
obs. P	.0543872						
pred. P	.0095941	(at x-bar)					

(*) dF/dx is for discrete change of dummy variable from 0 to 1
z and P>|z| are the test of the underlying coefficient being 0

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs – ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs – MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income – MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

4.1.7 Adoption of Tara Pump Technology

Nearly 7 percent households in our sample were using Tara pump.

- Adoption of TP technology is independent of income, and information on AMTs at the household level.
- Probability of adoption of decreases by 0.179 for each 1000 taka increase in the O&M costs (annual) of TP. It also decreases by 0.03 for each 1000 taka increase in the installation charges. So, O&M costs are a major deterrent for adoption. Interestingly, there is not much O&M costs for TPs.
- Probability of adoption of TP technology increase by 0.004 for each level rise in educational attainment. Educational level is measured as 0 means illiterate, 1 means primary, 2 means high school, 3 means secondary and 4 means higher than secondary.
- Probability of adoption of TP increases by .001 for each point rise in the wealth index.
- Probability increase by 0.039 with media exposure – meaning that people with media exposure are likely to adopt this technology than people with no media exposure.

Overall, TP technology is provided by NGOs and also by LGIs. Table 4.1 shows that this technology needs only installation costs and the O&M costs in very negligible and so is not picked up using a regular charges.

Table 4.1.g: Adoption of Tara Pump Technology – Probit Analysis

```
. probit tp ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood =  -348.3956
… …
Iteration 5:   log likelihood =  -306.1211

Probit estimates                                  Number of obs   =       1379
                                                  LR chi2(7)      =      84.55
                                                  Prob > chi2     =     0.0000
Log likelihood =  -306.1211                       Pseudo R2       =     0.1213

------------------------------------------------------------------------------
          tp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ctaka1 |  -.0020694   .0006638    -3.12   0.002    -.0033704   -.0007683
      ctaka2 |  -.0003991   .0001123    -3.55   0.000    -.0006192    -.000179
      edumax |   .0489332   .0208242     2.35   0.019     .0081186    .0897477
     pcincom |  -.0000384   .0000361    -1.07   0.287    -.0001091    .0000322
      windex |   .0117244   .0033295     3.52   0.000     .0051987    .0182501
       media |   .4824852   .1458077     3.31   0.001     .1967072    .7682631
       AMTs  |  -.1717252   .1130321    -1.52   0.129    -.3932641    .0498138
       _cons |  -2.242159   .1813365   -12.36   0.000    -2.597572   -1.886746
------------------------------------------------------------------------------

note: 4 failures and 0 successes completely determined.

. dprobit tp ctaka1 ctaka2 edumax  pcincom windex media AMTs

Iteration 0:   log likelihood =  -348.3956
… …
Iteration 5:   log likelihood =  -306.1211

Probit estimates                                        Number of obs =   1379
                                                        LR chi2(7)    =  84.55
                                                        Prob > chi2   = 0.0000
Log likelihood =  -306.1211                             Pseudo R2     = 0.1213

------------------------------------------------------------------------------
      tp |      dF/dx   Std. Err.      z    P>|z|     x-bar  [    95% C.I.   ]
---------+--------------------------------------------------------------------
  ctaka1 |  -.0001797   .0000514    -3.12   0.002   87.2335   -.00028 -.000079
  ctaka2 |  -.0000347   9.83e-06    -3.55   0.000   225.225  -.000054 -.000015
  edumax |   .0042498   .0018324     2.35   0.019    3.4409   .000658  .007841
 pcincom |  -3.34e-06   3.12e-06    -1.07   0.287   1480.63  -9.5e-06  2.8e-06
  windex |   .0010183    .000299     3.52   0.000   40.0654   .000432  .001604
   media*|   .0398154   .0114045     3.31   0.001   .584482   .017463  .062168
   AMTs *|  -.0152407   .0102285    -1.52   0.129   .564177  -.035288  .004807
---------+--------------------------------------------------------------------
  obs. P |   .0696157
 pred. P |   .0403867  (at x-bar)
------------------------------------------------------------------------------
(*) dF/dx is for discrete change of dummy variable from 0 to 1
    z and P>|z| are the test of the underlying coefficient being 0
```

NOTE ON VARIABLES
ctaka1 = Annual O&M Costs - ANNUAL MEASURED IN TAKA
ctaka2 = Installation Costs - MEASURED IN TAKA
edumax = highest educational attainment in the household
0 ILLITERATE, 1 PRIMARY, 2 HIGH SCHOOL, 3 SECONDARY, 4 HIGHER LEVEL
pcincom = percapita income - MEASURED IN TAKA PER YEAR
windex = wealth index (0- 100)
media = Level of media awareness (0=none,1 = at least exposed to TV/Radio /Newspapers)
AMTs = awareness on Arsenic Mitigating Technologes (0 = no, 1 = yes).

5.0 Policy Options

In this study, we have studied seven major technologies being provided by government and non-government organizations to combat arsenic related disasters on human health. The study finds that in terms of adoption, information and proper information provides a major role for adoption of technologies. It has also found that some technologies are more popular among educated groups compared to others. Table 5.1 summarizes the results.

Table 5.1: Factors Affecting the Probability of Households in Adopting of AMT

	DW	DTW	PSF	PWSS	CRWHS	AIRP	TP
Annual Cost of O&M				0.00002	-0.00025	-0.00026	-0.00018
Initial Costs	-0.00014	0.00005	-0.00008		0.00001	0.00000	-0.00003
Educational Status	-0.01760	0.03657	-0.01648	-0.01484	-0.00339	-0.00190	0.00425
Per capita Income					0.00000		
Wealth Index	-0.00182		0.00138			-0.00023	0.00102
Media exposure	-0.04720	0.11734	-0.13599	-0.03342		0.01474	0.03982
AMT awareness	0.09408	-0.28280		0.06825	0.01523	0.01317	

NOTE: Figures in the table represents changes in the probability of adoption.

DW – Dug Well, DTW – Deep Tube Well, PSF – Pond Sand Filter, PWSS – Piped Water Supply System, CRWHS – Community-based Rain Water Harvesting System, AIRP – Arsenic and Iron Removal Plant, TP – Tara Pump

Table 5.1 implies the following for policy makers.

- Higher O&M costs may deter poor households to adopt CRWHS, AIRP and TP technologies
- For DTW, CRWHS, AIRP technologies people are willing to pay more for a better service.
- Illiterate households prefer DTW and TP technologies.
- Income poverty is not a major deterrent for adoption of technologies as most of them are provided by the NGOs and Government Agencies.
- Asset poor households prefer DW, AIRP technologies.
- Media exposure is a very important variable to influence decisions related to adoption or rejection of technologies. Consequently, government should use appropriate messages on Radio, TV and Newspapers to influence the decisions.
- With the current strategy of communication that exists in Bangladesh media, households with media exposure do not like to use DW, PSF, and PWSS technologies.
- Providing information on AMTs will significantly improve adoption of DW, PWSS, CRWHS and AIRP technologies. It is also a major variable to influence the decision at the household level.
- Interestingly, the current level of information on DTWs is working against this technology despite the fact that this technology is the most poor-friendly technology.

References

Ahmed, M.F., (2001). An overview of arsenic removal technologies in Bangladesh and India, Presented at the BUET-UNU International Workshop: "Technologies for Arsenic Removal from Drinking Water," Dhaka, Bangladesh, 5-7 May.