Study

Water and Sanitation Program

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An international partnership to help the poor gain sustained access to improved water supply and sanitation services

Fighting Arsenic: Listening to Rural Communities

Willingness to Pay for Arsenic-Free, Safe Drinking Water in Bangladesh

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THE WORLD BANK

Bangladesh Rural Advancement Committee

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Foreword

For many years, experts, and aid agencies determined how water was to be supplied to rural and urban communities. However, the culture of 'expert knows best' has slowly given way to considering people who matter — the consumers. Participatory techniques have been used to elicit community preferences, and economists have contributed substantially to these procedures through the application of 'stated preference' analysis. In stated preference, opinions and willingness to pay of individuals are sought about the issue in question, in this case, water. Compared to non-economic procedures, stated preference techniques are not only participatory but are also founded in the rigors of statistical theory and economics. If nothing else, this ensures consistency and comparability across studies. Increasingly, these techniques are being applied to major issues such as malaria risks, the loss of ecosystems, types of crop, soil conservation measures, and so on.

It is a privilege to introduce one of the most important studies to tackle a major environmental and health issue.

The authors of this study have confronted the issue of an insidious pollutant, arsenic in the drinking waters of Bangladesh, arising from natural geological events. The scientists and politicians, it seems, have for long known about the issue. The population at risk, however, knows far less about it, and less still about the risks they incur by consuming contaminated groundwater. But that raises a policy challenge. If there is no public clamor, for instance about just how much money, which is scarce, should be allocated to solving it, the cheapest solutions, and above all, what do people themselves think about the alternatives, then the issues will not be resolved.

Some would argue that the solutions should be devised independently of public opinion. It is far more tenable to argue that whatever is done must be informed by what people say they want. This is why the study in this report is so important. It tells us what the people say and how they rank the options available.

FOREWORD

The dominant finding is clear. Bangladesh's 'dream' of supplying water to all through tubewells is over. Nature conspired to kill the dream by contaminating the very water to be supplied. People want piped water and it appears that an almost incidental benefit of the solution is the absence of arsenic. Though, nearly all the willingness to pay for piped water is based on the convenience factor, not the absence of arsenic contamination in the water. If that seems a counter-intuitive finding, it may not be. The study shows just how limited people's information is about the risks of arsenic contamination over time. There are time lags involved and familiar problems that arise in most risk studies — risks are what others bear not what we bear. The study in this report is packed with detailed information about risk perceptions and about how people see the alternative options to reduce those risks.

This study is perhaps one of the most important stated preference studies to have taken place in the developing world. Academics will learn from the ingenious manipulation of the data, but, above all, those who make public policy must learn from its conclusions. Research is important, but turning the results into practical policy for the benefit of vulnerable people is more important.

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The Research and Evaluation Division of BRAC, Bangladesh, meticulously managed and implemented the field survey, including data entry and prepared the basic tabulation scheme. Special mention must be made of the enthusiasm of the supervisors and enumerators in conducting the survey. Dr. Mushtaq, Head of the Research and Evaluation division of BRAC, in particular, played a critical role in taking the study forward. Mr. Jakariya and his colleagues successfully managed the field survey and the team, in addition to contributing to the survey design and the sampling frame.

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Executive Summary

During the last couple of decades, the efforts of the government, NGOs, and donor agencies have succeeded in creating a 'water miracle' in Bangladesh. A combination of three important factors has enabled over 95 percent of rural households to access clean, drinking water through tubewells: the shallow water aquifers of the country, a sustained public sector campaign encouraging people to shift from pathogen-contaminated surface water to ground sources, and the introduction of handpump technology. The shallow tubewell technology, purchased directly by households from the market, created perhaps the largest private sector supported safe drinking water program in South Asia, if not the developing world.

However, the contamination of shallow aquifers with arsenic may well be threatening to undo this success. Arsenic contamination of the groundwater has been detected in 59 of the 64 districts, and 249 of the country's 463 sub-districts. In some villages, 90 percent of the tubewells are unsafe and there are few alternatives to groundwater sources. Estimates suggest that about a quarter of the 6-8 million tubewells in Bangladesh may contain arsenic levels more than 50 ppb or 0.05 mg/l, the national standard for drinking water set by the Government of Bangladesh. A much higher proportion of tubewells would be violating the current WHO guideline for the maximum permissible level of arsenic in drinking water of 10 ppb or 0.01 mg/l.

While the figures are unconfirmed, estimates indicate that between 30-40 million people, out of a population of 129 million, are potentially at risk of arsenic poisoning from drinking water sources in Bangladesh. Several thousand people with arsenic-related skin diseases have been identified in field surveys. Even, deaths due to arsenic-induced cancer have been reported in recent years and the number is likely to increase.

Bangladesh, therefore, urgently needs to find effective, acceptable, and sustainable solutions to address the problem of arsenic contamination. Numerous bilateral and international agencies, the government and NGOs are involved in arsenic research, testing, and mitigation activities. However, solutions so far have focused mainly on issues on the primarily 'supply side'. Research has mainly been conducted on the engineering aspects of arsenic mitigation technologies, to assess whether the technology is effective, and on the hydrological properties of alternate sources of water and their potential to become contaminated in the future. The economic and institutional issues of propagating new technologies and approaches to ensure household access to safe drinking water have largely been ignored. Little effort has been made to understand people's preferences for arsenic-free drinking water and whether they are willing to contribute to the cost of arsenic mitigation technologies. In particular, people's willingness to share the costs for more robust and sustainable solutions, such as rural piped water supply, has not been explored.

This study has been designed to assess and analyze people's perceptions of the extent of the arsenic problem and possible solutions. It examines people's willingness to pay for arsenic-free safe drinking water options in rural Bangladesh, the factors that influence the demand for these options (particularly the demand for piped water supply), and the preferences for various household/community-based arsenic mitigation technologies.

Studies so far have largely ignored the potential of local piped water systems to provide a sustainable solution to the arsenic problem. It has been assumed that piped water networks are expensive to set up, and that communities may not be willing and able to meet the capital and recurring costs of such schemes. It is also believed that network systems introduce an element of monopoly, and it would require greater public intervention to regulate and manage these schemes. These factors may have contributed to the limited appeal of the technology.

In contrast, it is believed that tubewells do not need to be managed by public institutions as households and communities can access the technology directly from the market. Thus, preserving the use of tubewell technology, if possible, has become an implicit if not an explicit goal of the approaches currently being advocated to address the drinking water crisis in Bangladesh. It is in this context, therefore, the study lays emphasis on piped water networks, and on whether the supply from this alternate water source is preferred to arsenic mitigation technologies used for treating tubewell water.

The study uses a contingent valuation methodology to assess household preferences and willingness to pay for arsenic-free drinking water. Various arsenic mitigation technologies, including accessing alternate arsenic-free sources, were discussed with the respondents, and their preferences and willingness to pay to access these options evaluated. The results were validated using the revealed preference approach, where the costs incurred by households that had shifted to alternate safe drinking water sources were compared with the stated willingness to pay.

The field survey was conducted between October-December 2001. Households were divided into sample and control areas. The sample area (2,430 households) covered the rural areas of three arsenic-affected districts — Chapai Nawabganj (a low water table area), Barisal (a coastal area), and Chandpur (a high water table area). These areas are representative of the available water resources, current levels of water consumption, and related aspects of convenience in accessing water in Bangladesh. Three hundred households were surveyed in the arsenic-free control areas — 150 from Bolarhat *thana* in Chapai Nawabganj district and 150 from Commilla Sadar *thana* in Commilla district. In addition, 150 households from Banaripara *thana* in Barisal district, an area marked by a large-scale shift to public tubewells was surveyed. Care was taken to ensure that the sample was representative by selecting households using the stratified random sampling method. To minimize the biases associated with contingent valuation studies, the survey was carefully designed and finalized after repeated pre-testing and focus group discussions. Efforts were made to ensure that quality data were collected.

Key findings

1. Household perceptions regarding the impact of arsenic exposure on health

Survey data reveal that most of the respondents (87 percent in the sample area and 53 percent in the control area) had some knowledge about the arsenic problem. Their sources of information varied from development agencies working in rural areas (NGOs/ government/other agencies), to other residents of the village, and public networks such as radio and television. However, most respondents were not aware of the serious health implications of consuming arsenic-contaminated water. In the arsenic-affected sample area, approximately half the respondents had some idea about the symptoms of arsenicosis, but only 35 percent knew that in the advanced stages, arsenicosis can lead to gangrene, cancer, or even death. For the control area the corresponding figure was only 4 percent. Thus, while the majority were aware of the arsenic problem, awareness levels about the likely effects on their health were found to be low.

The lack of awareness of the serious health effects of consuming arsenic-contaminated water in the arsenic-affected areas suggests that there is a low risk perception of arsenicosis and the dangers of the presence of arsenic in the water in general, though this is difficult to assess directly from the study. The results of the statistical analysis of willingness to pay support this inference. Clearly, the issue of risk perception is an important area that needs a more detailed analysis.

2. Extent of arsenic contamination of tubewells in the areas surveyed

Roughly 58 percent of the households in the sample area reported that the tubewell nearest to their house had been tested for arsenic. In the control area, less than 1 percent of the households reported such a test. This indicates that while the majority of tubewells in the arsenic-affected areas had been tested, a significant proportion still remained to be covered.

The survey reflects a marked inter-district variation in the level of contamination. Of the tested tubewells in Chandpur (reported by households in the survey), over 90 percent had been found to be arsenic-contaminated. The proportion was much lower in the arsenic-affected areas of Chapai Nawabganj (23 percent) and Barisal (41 percent). In the sample area as a whole, 61 percent of the tested tubewells were found to be contaminated with arsenic.

3. Shift to alternate safe sources of water by households encountering an arsenic problem

Roughly 35 percent of the households in the sample area had directly encountered the problem of arsenic contamination. About 59 percent of these households (approximately 20 percent of the total sample) had shifted to alternate safe sources, mainly public deep tubewells. However, the remaining 41 percent (about 15 percent of the total sample) were continuing to use tubewells that were known to be arsenic-contaminated primarily because there was no suitable alternate source. Only 1 percent of the respondents were unconcerned about the consequences of arsenic poisoning.

4. Household preferences among arsenic mitigation technologies

Six technologies were selected for the study: three-*kolshi* (pitcher) method, activated alumina method (household-based), activated alumina method (community-based), dugwells, pond sand filters, and deep tubewells. These technologies represent both arsenic reduction units (the three-*kolshi* method) as well as technologies that use alternate safe water sources (pond sand filters and deep tubewells).

The survey data reveal that, based on considerations of risk and convenience (disregarding capital and recurring costs), the dominant preference was for community-based technologies. About 72 percent preferred a community-based technology while 28 percent opted for household-based technology. When respondents were asked to choose from the six technologies after taking into consideration capital and recurring costs, convenience, associated risks, and the advantages and disadvantages of each technology, about 76 percent expressed a willingness to pay for and use one or more of these technologies. The overwhelming preference was for deep tubewells — the most preferred option for 1,331 out of 1,854 respondents (72 percent). The three-*kolshi* method was the second most preferred option, with 291 (16 percent) ranking it first and another 490 (27 percent) ranking it second. Dugwells and pond sand filters were given low preference.

5. Respondents' current experience with arsenic mitigation technologies

About 40 percent of the respondents reported that they had used or were currently using one or more of the six selected arsenic mitigation technologies. Of these 915 respondents, 891 had used/were using deep tubewells, 20 respondents had used/were using the three-*kolshi* method, 5 respondents had used/were using equipment based on activated alumina technology, and 7 respondents had used/were using dugwells or pond sand filters (a few respondents had used more than one technology). Various problems were reported in using the technologies: low rate of water flow, clogging of filter, uncertainty regarding arsenic removal to safe limits, high recurring costs, and difficulties in maintenance. The most common complaint regarding government-constructed deep tubewells was the distance that had to be covered to collect water.

6. Perceived advantages of piped water systems

The survey results indicate that respondents perceived a number of advantages in a piped water supply system. In the sample area, about 60 percent of the respondents felt that piped water supply systems would deliver clean water (referring to the physical properties of water, such as being free from excess iron), 47 percent felt that it would be good for health, and 48 percent felt that it would be convenient. The perceived advantages of piped water supply systems in the control area were largely similar. About 85 percent felt that a piped water supply system would provide clean water, 46 percent felt that it would be good for health, and 37 percent felt that it would be convenient. A related question regarding the advantages of having a domestic piped water connection was also asked. Not surprisingly, convenience was perceived to be the main advantage by more than 70 percent of the respondents in the sample and control areas.

The quantity of water available did not emerge, as a major issue underlying the demand for piped water in rural households as only a small proportion of the respondents were dissatisfied with the quantity of water currently being accessed. Rather, water quality and convenience were perceived to be the main advantages of piped water.

7. Households' willingness to pay for piped water systems

A multinomial logit model was applied to the survey data to econometrically analyze household preferences for piped water supply and derive estimates of mean willingness to pay for such a service in the sample and control areas, and among poor and non-poor households.

- **Determinants of willingness to pay.** The results of the analysis indicate that the demand for piped water in the arsenic-affected areas increases with income and declines with an increase in the charges for a piped water supply. The results also indicate that the higher the awareness and concern for arsenic contamination (measured by an arsenic score constructed from nine arsenic-related variables), the greater is the inclination to opt for piped water supply. Considerations of convenience and benefits to health were found to be significant factors influencing household demand for piped water. Education (above Class X) also increased the demand for a domestic piped water connection. Further, households where the head was a farmer or in business or service were relatively more inclined to opt for piped water supply than households where the head was an agricultural laborer or engaged in other types of manual work.

The results for the control (arsenic-free) area were similar to those for the sample area. Household income and the cost of the service were important factors influencing the demand for piped water. As in the sample area, the convenience of piped water supply significantly influenced household demand for piped water in the control area.

- **Willingness to pay for capital and recurring costs in the sample area.** In the arsenic-affected sample area, the estimated mean willingness to pay for the initial capital cost was Tk[1] 960 for a standpost and Tk 1,787 for a domestic connection. The monthly estimated mean willingness to pay towards recurring costs was Tk 51 and Tk 87, respectively. In Chandpur, the estimates of willingness to pay were higher than in Barisal and Chapai Nawabganj possibly because of higher average income levels and a greater concern for the problem.

  Among poor households (monthly household income less than Tk 3,600), the estimated mean willingness to pay was Tk 838 as the capital cost for a public standpost and Tk 1,401 for a domestic connection. The estimated mean willingness to pay towards the monthly recurring costs was Tk 44 per month and Tk 68 per month, respectively. Non-poor households were willing to pay significantly more than poor households.

- **Comparison of willingness to pay and the actual cost of piped water supply in the sample area.** In the sample area, the mean willingness to pay of households more than covers the actual O&M cost of piped water supply (based on cost estimates of on-going schemes in Bangladesh). The average willingness to pay for recurring costs for standposts was 46 percent higher than the actual costs, while for domestic connections the willingness to pay was 40 percent higher. Among poor households, the mean willingness to pay for standposts exceeded the O&M costs by more than 26 percent and exceeded the actual cost by 10 percent for a domestic connection.

  Beneficiaries in rural water supply projects in developing countries are often asked to contribute 10 percent to the capital cost of the projects and meet the entire O&M costs. These norms are being followed in India, for example, in implementing one of the largest government-financed rural drinking water programs under the Rajiv Gandhi National Drinking Water Mission, targeting about 70 million people across 29 states. The willingness to pay estimates for the arsenic-affected areas of Bangladesh indicate that rural households, both poor and non-poor, would

[1] One Taka is approximately US$ 0.017 (August 2002).

be willing to share more than this percentage of the capital cost and meet the entire O&M costs of piped water supply projects. The mean for all households was 18 percent of the capital costs for standposts and 17 percent of the capital costs for a domestic connection. While poor households on an average were willing to pay 16 percent of the capital cost for standposts and 13 percent of the capital cost for a domestic piped water connection, non-poor households were willing to pay 21 percent of the capital cost for standposts and 22 percent of the capital cost for a domestic connection.

- **Willingness to pay for piped water in the control area.** The estimates of willingness to pay among households in the control area were similar to those for the sample area (a little lower in the case of public standposts). The estimated mean willingness to pay in the control area exceeded the actual O&M cost of piped water supply and was more than 10 percent of the capital cost for public standposts and domestic connections among both poor and non-poor households.

- **Willingness to pay and affordability.** On an average, rural households in the sample area were willing to pay about 1.1 percent of their monthly income as O&M charges for public standposts and about 1.9 percent of their monthly income as O&M charges for a domestic piped water connection. To meet the capital cost, households in the sample area were, on an average, willing to pay about 1.7 percent of their annual income as a one-time payment for a public standpost, and about 3.2 percent of their annual income for a domestic connection.

  Mean willingness to pay, as a percentage of income in the control area was similar to the sample area. For instance, households in the control area were, on an average, willing to pay 1.0 percent of their monthly income as O&M charges for public standposts and 2.0 percent of their monthly income as O&M charges for a domestic connection. The finding that the average willingness to pay is a small percentage of mean household income, and is adequate to cover the recurring cost of piped water supply and the frequently stipulated share of the capital cost of such schemes, indicates that piped water supply systems may well be affordable in many rural areas of Bangladesh.

- **Value of arsenic-free water.** Based on the estimated willingness to pay functions for the sample and control areas, the study estimated the value of arsenic-free water out of the total value of piped water to rural households in the arsenic-affected areas of Bangladesh. The estimated value of arsenic-free water to a household was Tk 10-13 per month. The arsenic-free component was found to be 9-14 percent of the value of piped water in the arsenic-affected areas for standposts and 9-19 percent for domestic connections. As a proportion of income, the willingness to pay for arsenic-free water was rather low, ranging from 0.2 to 0.3 percent. The low value of arsenic-free water probably reflects the long latency period of arsenicosis, the high personal discount rate for the future among rural households, and limited information on the levels and dangers of arsenic contamination.

- **Validation of the estimates for willingness to pay.** To validate the estimate of the value of arsenic-free water based on the contingent valuation approach, an alternate estimate was made by using the revealed preference approach. When using the revealed preference approach, the value of arsenic-free water was computed based on the costs borne by households as a result of shifting to safe water sources or other action taken to address the problem of arsenic contamination of tubewells. Two important elements of cost considered in the study were:

- The value of the extra time spent collecting drinking water by households that had shifted their drinking water source
- The value of time spent and fuel used to boil water to remove bacteriological contamination among households that had shifted to sources such as tanks and ponds.

The estimated value of arsenic-free water to a household obtained by the revealed preference approach was between Tk 12.5-16.2 a month. These estimates of the value of arsenic-free water, obtained through the revealed preference approach, are broadly in agreement with the estimate made by the contingent valuation approach, and thus validate the estimates of the latter approach.

8. Preference between arsenic mitigation technologies and piped water systems

During the survey, the respondents were asked to state their preference between piped water supply and their most preferred arsenic mitigation technology (out of the six selected for the study). The responses clearly indicate that taking into consideration costs and other aspects, the preference was predominantly for piped water supply (about 89 percent) over any of the arsenic mitigation technologies. Even with the assumption of an 80 percent capital subsidy on arsenic mitigation technologies, the proportion of respondents preferring piped water supply remained high (about 78 percent).

The main reasons for choosing a piped water supply system over other arsenic mitigation technologies were convenience, and being able to access water free from arsenic as well as bacteriological contamination. Of the 2,023 respondents who chose piped water over other arsenic mitigation technologies, 69 percent mentioned convenience of piped water as the main reason or one of the reasons for preferring this option.

Among respondents who had no experience of arsenic mitigation technologies, there was a strong preference for piped water (90 percent). However, the preference for piped water was equally strong among households that had used or were currently using arsenic mitigation technologies. About 90 percent of the households that had used the three-*kolshi* method or activated alumina technology, and about 80 percent of the households that had used deep tubewells, expressed a preference for piped water over their most preferred arsenic mitigation technology.

9. Demand for piped water in arsenic-affected areas with access to deep tubewells

As mentioned earlier, 150 households in five villages from Banaripara *thana* of Barisal district were surveyed to investigate whether households in areas marked by access to safe water through public tubewells would prefer an alternate source of water supply, such as piped water. The results indicate that households that were currently using public tubewells were also strongly inclined to access piped water. This may be due to the long distances and the time required to collect drinking water from public tubewells.

The mean willingness to pay for piped water schemes in Banaripara was estimated using the multinomial logit model. The findings show that households were willing to share the cost of piped water schemes. The mean willingness to pay for standposts was Tk 63 per month as O&M cost and Tk 1,382 as initial capital cost. For a domestic connection, the mean willingness to pay was Tk 126 as O&M cost and Tk 2,482 as initial capital cost. These figures are higher than the estimates of the mean willingness to pay in the sample and control areas. Evidently, a strong demand for piped water supply exists not only in arsenic-affected areas but also in areas free from the arsenic problem as well as areas where the construction of public deep tubewells has provided the households access to arsenic-free safe drinking water.

The road ahead

The findings of the field study offer insights for policy makers to evolve a framework to address the arsenic crisis. Lessons that can be drawn from the study are as follows:

1. Unless household-level filtering systems become affordable, convenient to use, and easy to link to shallow tubewells, the 'water miracle' in Bangladesh may be reversed. The convenience offered by shallow tubewells will make it difficult to promote alternative solutions such as ponds and dugwells. Alternatives to tubewells would need to provide access to safe water as well as the convenience of tubewell technology. Thus, when designing an emergency response to the arsenic crisis, the government and donors would need to take into consideration household preferences to ensure that the options offered are effective in mitigating arsenic and sustainable in the long term.
2. There is a strongly voiced preference for piped water systems. The density of rural settlements in Bangladesh and the growth of rural incomes over the last two decades may have made piped network systems more affordable. Piped water systems, with their central treatment facility, are more effective than household-level technologies in addressing arsenic contamination as the system can be managed and monitored at a central location. Moreover, the technology used for treatment can easily be upgraded at a central point whenever required. Another advantage of a central filtration system is that it allows for the treatment of pathogenic contamination of surface water, which may enable rural communities to return to the use of surface water that is free of arsenic contamination, but in the context of a more convenient technology.
3. The policy challenge facing Bangladesh in exploring the potential of piped water systems in rural areas is to assess the feasibility of delivering these through alternative organizations that are responsive to rural consumers. In particular, it is important to assess the potential of delivering network systems through independent (non-public) service providers. Bangladesh's experience with rural cooperatives managed by the Rural Electricity Board, and service delivery through NGOs in areas as diverse as education and micro-credit, suggests that Bangladesh has local organizations that can play the role of such service providers. Indeed, the piped water network systems introduced by the Rural Development Academy in the Bogra area suggest the potential of such systems in Bangladesh.
4. The estimates of willingness to pay obtained in this study indicate the possibility of introducing a demand-driven program to expand the coverage of rural drinking water schemes similar to the program currently being implemented in India, with the potential of raising an even higher contribution from households. This hypothesis can be validated by promoting piped water pilots on the ground to enable active learning or action research. Several pilot piped water projects have been initiated that could provide additional inputs to the government on the appropriateness of this technology and possible institutions that could ensure delivery and access to safe drinking water in rural Bangladesh.
5. Though there is a strong preference for piped water, households should not be offered a one-point solution, as a significant number of households may prefer other technologies. While the areas sampled in this study reflect the socio-economic profile of rural Bangladesh, there

are some areas where population density and income levels may warrant a household-based technology. Keeping the option of choice open is important, especially in a context where technologies and technology costs may be constantly changing. It should be noted from the findings that the preference for piped water is driven more by the convenience factor and less by the issue of arsenic, reflecting perhaps a growing structural shift in the preferences of rural households for water services. This shift is largely independent of the arsenic crisis but nevertheless strengthened by it.

6. The study clearly brings out the low level of knowledge and awareness of the health effects of arsenic contamination, even in arsenic-affected areas. For a national crisis of the magnitude that Bangladesh is currently facing, household and public awareness of arsenic contamination, its seriousness in terms of its effect on public health, and various technology options need to be increased.

7. The government should play a more important role in the drinking water sector because many of the issues that need to be addressed when tackling the arsenic problem, such as dissemination of information, ensuring choice and options, monitoring of water quality, and most importantly managing the introduction of a network system, require the government's involvement on a large scale. During the 1980s, the role of the government in rural water supply diminished greatly as the private sector spearheaded and supported the installation of tubewells across the country. The new situation calls for a revival of the assertive role of the government. In this context, the role of local governments in the drinking water sector in Bangladesh needs to be explored. In the unitary structure of government in Bangladesh, local governments have not been given the space to emerge as key players in the management of service delivery at the local level. Yet, by nature, local governments are closest to a crisis of the kind being experienced in the drinking water sector where alternative solutions will be specific to local contexts. The arsenic crisis has opened the door to rethink the role of local government in Bangladesh. Can local governments be empowered to manage a community-based response to the arsenic crisis? Can local governments support the emergence of independent service providers in rural areas thus drawing on existing NGO capacity? These are critical issues of local governance being brought out as a direct result of the arsenic crisis.

8. Another issue indirectly raised by the study is the significance of monitoring water quality. In the euphoria of the private sector-led approach to drinking water delivery, the issue of monitoring water quality was largely ignored in Bangladesh. Arsenic contamination has now raised the issue of institutionalizing mechanisms to monitor water quality in the country. Establishing standards, creating an independent water regulatory agency, developing a monitoring process, and linking this with local governments are policy issues that require to be addressed even as immediate solutions to the arsenic crisis are developed.

Further research

This study raises a number of issues that may guide future research. An important issue is to establish the extent that 'stated' willingness to pay could be translated into 'actual' willingness to pay, and the role of institutional arrangements for service delivery in this regard. With the implementation of more pilot piped water supply projects in rural areas with different institutional models of delivery, it would be possible to study the responses to this issue.

This study and its methodology is only one source of information for policy makers; the pilots being implemented will provide equally important inputs.

In this context, BAMWSP, the World Bank-funded project of the Government of Bangladesh, which has not considered piped water as an option, offers an alternative to verify the findings of this study and to compare alternatives for arsenic mitigation, with and without piped water.

Two other issues that need further study are the economic cost of arsenicosis, and the risk perception of rural households. The economic cost of arsenicosis can be studied by using the value of statistical life approach. Some estimates of the economic cost of arsenicosis would be helpful to assess the wider economic significance of the problem. An important concern with regard to risk perception is why the value of arsenic-free drinking water to rural people is low compared to household income despite the fact that arsenic contamination has serious health effects. It would be useful to study the reasons why households attach low value to arsenic-free water, and relate the findings to the time preference of rural households and their risk perceptions.

A final word

The study highlights that the demand-side approach is essential to understand the arsenic problem and to inform policy makers of appropriate policy options to address the arsenic crisis. It suggests that the arsenic problem is not merely a problem of technology but is as much, if not more, an issue of institutions — private and public — that influence the financing and delivery of safe water. The voice of communities, their perceptions about the value of water and indications of what they are willing to pay for delivery of water services can help support the evolution of sustainable institutions.

Although this study has only touched the surface of a major crisis in rural Bangladesh, it is noteworthy in its use of the methodology to access and interpret data from the communities themselves. The study establishes that the principle of listening to rural communities must remain the guiding force for approaches to institutionalize change in the rural drinking water sector and to address the arsenic crisis in Bangladesh.

Abbreviations

AMT	Arsenic mitigation technology
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BRAC	Bangladesh Rural Advancement Committee
BUET	Bangladesh University of Engineering and Technology
CSERGE	Centre for Social and Economic Research on the Global Environment
DANIDA	Danish International Development Agency
DFID	Department for International Development
DPHE	Department of Public Health Engineering
HH	Household
lpcd	liters per capita daily
mg/l	milligrams per liter
NGO	Non-governmental organization
O&M	Operation and maintenance
PPB	Parts per billion
RDA	Rural Development Academy
R&D	Research and Development
SSC	Senior School Certificate
UN	United Nations
UNICEF	United Nations Children's Fund
US	United States of America
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WPP	Watsan Partnership Project
WSP-SA	Water and Sanitation Program–South Asia

1 Background

In most areas of Bangladesh, groundwater has dangerously high levels of arsenic contamination and the number of people affected by arsenic is the largest facing any disease in the world today (WHO, 2002). Estimates of the number of people, in Bangladesh, exposed to unsafe levels of arsenic in their drinking water varies from 28-35 million to a high of 77 million people (Ahmed and Ahmed, 2002:99; WHO, 2002). These figures would mean that between a quarter to half of the total population of the country, estimated at about 129 million as on July 2000 (Ahmed and Ahmed, 2002; UN, 2000), is at risk of exposure.

The problem of arsenic-contaminated tubewells in Bangladesh was identified in the early 1990s. Traditionally, shallow ponds were the source of drinking water. However, due to the lack of adequate sanitation facilities and high population density, these sources were often polluted with microbiological contaminants, resulting in high morbidity and mortality from diarrheal disease. In the early 1970s, nearly a quarter of a million children died every year from water-borne diseases (World Bank, 2000).

To provide safe drinking water and reduce the incidence of water-borne diseases, the Government of Bangladesh, with the support of international agencies, particularly UNICEF, actively promoted the use of groundwater in the 1970s, and a large number of shallow tubewells were installed (WHO, 2000). During the 1980s, UNICEF's support for installing tubewells decreased, as the private sector's participation in the program increased, and a large number of tubewells were supplied and installed with their support (Smith et al., 2000:1094). The task of installing these tubewells, which are drilled to a depth of less than 200 meters, was relatively simple and inexpensive as the water table is relatively high in Bangladesh, and geological conditions are favorable. This program achieved extensive coverage and, by the early 1990s, over 2.5 million shallow tubewells had been installed (Caldwell et al., 2003). Through the remarkable success of the program a 'water miracle' was created, and almost the entire rural population was provided with bacteriologically safe tubewell water. At present, there are about 6 to 8 million shallow tubewells in the country (Ahmed and Ahmed, 2002:92)[2] and 97 percent of the rural drinking water

[2] Some estimates place the number of tubewells in Bangladesh at 8 to 12 million (WHO, 2001).

supply in Bangladesh is obtained from groundwater (WSP-SA, 2000).

The installation of tubewells is perceived to have positively impacted health indicators. The infant mortality rate in Bangladesh declined from 151 per 1,000 to 83 per 1,000 between 1960 and 1996. The under-five mortality rate also decreased from 247 per 1,000 to 112 per 1,000 during this period (UNICEF, 1998).

Paradoxically, the same tubewells that had improved the health status of the population now pose a health hazard due to arsenic contamination. In 1993, water samples from the tubewells in Bangladesh were found to contain high levels of arsenic (Smith et al, 2000:1,954; WHO, 2000:3; World Bank, 2000). However, it was not until 1995 that contamination was shown to be widespread across central and southern Bangladesh (Caldwell et al., 2003). Recent studies of water quality indicate high levels of arsenic in the groundwater in most districts of the country (WSP-SA, 2000) and a number of deaths have been linked to the long-term ingestion of arsenic-contaminated water.

1.1 Health effects of exposure to arsenic-contaminated drinking water

Arsenic is poisonous even at very low concentrations. As little as 0.2-0.3 g of arsenic trioxide (As_2O_3) can be fatal in an adult. Its toxicity depends on the quantity of arsenic ingested. Although most ingested arsenic is excreted from the body, when arsenic-contaminated water is consumed in large quantities, some amount gets deposited in the tissues of the body. This inhibits cellular enzyme activities, leading to arsenicosis.

The standards for safe levels of arsenic in drinking water vary. Current WHO guidelines for the maximum permissible level of arsenic are 10 ppb or 0.01mg/l. The Governments of Bangladesh and India have set a higher permissible standard for safe drinking water at 50 ppb or 0.05 mg/l.

Chronic long-term exposure to arsenic through drinking water has an adverse effect on health (Ahmed and Ahmed, 2002; Smith et al. 2000; WHO, 2000). Arsenic exposure can cause cancer of the skin, lungs, liver, bladder and kidneys, as well as debilitating skin lesions, pigmentation changes (dark or light spots on the skin), and thickening of the skin (keratosis). Long-term exposure is also associated with peripheral vascular disease, leading to gangrene of the extremities (WHO, 2000). Cardiovascular conditions such as hypertension and ischemic heart disease, as well as pulmonary disease, diabetes mellitus, and anemia are also associated with arsenic exposure (WHO, 2000).

The initial effect of long-term arsenic exposure is usually pigmentation changes in the skin, followed by keratosis.[3] Cancer is a later phenomenon, and normally takes more than 10 years to develop (WHO, 2001).

The higher the level of arsenic in the drinking water, the greater the risk of developing cancer. For instance, if the level of arsenic is 0.5 mg/l, the risk of developing cancer will be about ten times more than the risk at arsenic concentration of 0.05 mg/l (Smith et al, 2000:1096).

Arsenic is a silent killer as the symptoms of arsenic toxicity may take several years before they become apparent. The latency period differs from person to person, depending on the quantity of arsenic ingested, nutritional status, level of immunity, and length of arsenic exposure (BRAC, 2000:1). Typically the latency period ranges between five to ten years. Malnutrition and poor socio-economic status can aggravate a person's vulnerability to arsenic toxicity.

Arsenic exposure leads to a number of social and economic problems that disproportionately affect the disadvantaged (Adeel, 2001; Khan and Ahmad, 1997). These include the loss of jobs and livelihood, and marital problems. In addition, the cost of health care and their potential social exclusion also have an adverse impact on affected persons (WHO, 2001).

[3] According to Guha-Mazumdar et al. (1998), it takes at least five years between the first exposure to arsenic and the initial cutaneous manifestation.

Box 1.1

Arsenic exposure and the incidence of cancer

Arsenicosis is a condition caused by prolonged exposure to arsenic above the safe level. It normally manifests itself through characteristic skin lesions and may affect the internal organs and cause malignancies (Ahmed and Ahmed, 2002:5). It is not infectious, contagious, or hereditary. Studies have shown that long-term exposure to arsenic can cause cancer of the skin and internal organs.

Long-term arsenic exposure has been linked to the incidence of cancer. While it is difficult to make precise estimations, studies indicate that if 1 liter of water containing 0.05 mg/l of arsenic is consumed a day, the lifetime risk of developing skin cancer would be 1-2 per 1,000 persons and the lifetime risk of dying from cancer of the liver, lungs, kidneys, or bladder would be 13 per 1,000 persons (Smith et al., 2000). According to the US National Research Council, the combined cancer risk at this level of exposure would be 1 per 100 persons (National Research Council, 1999).

There is no effective treatment for arsenicosis. However, since the effects of arsenic exposure can be significantly reversed by drinking water free of arsenic, the most important remedial action is to prevent further exposure by providing safe drinking water (Ahmed and Ahmed, 2002; Smith, et al., 2000:1098; UNICEF, 2000).

1.2 Impact of arsenic exposure in Bangladesh

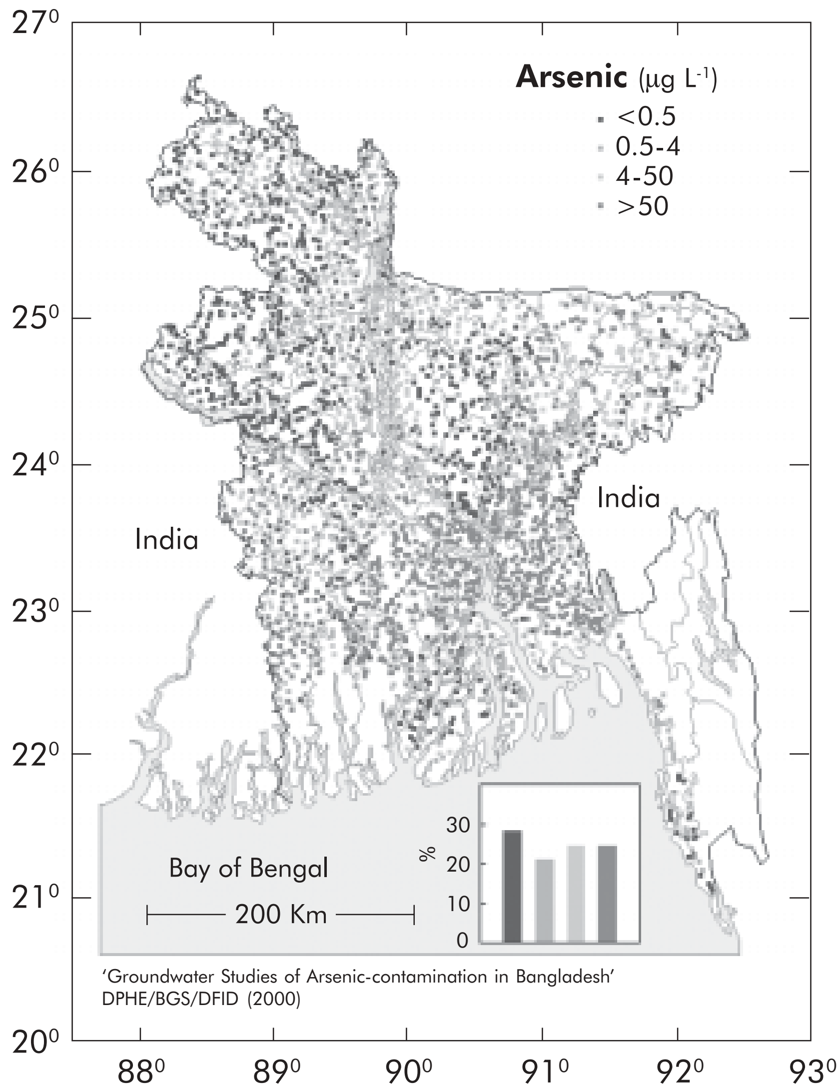
As a result of contaminated water supplies, Bangladesh is currently facing a long-term epidemic of cancers and other fatal diseases related to arsenic exposure, the extent of which is difficult to determine. By the end of the 1990s, there were about 7,000 identified persons affected by arsenic-contaminated drinking water (Karim, 2000). This figure has now reached over 10,500 (Ahmed and Ahmed, 2002:61). However, these estimates may be only the tip of an iceberg. A survey of 3,780 randomly selected households in Bangladesh conducted by the National Center for Epidemiology and Population Health, Canberra, has estimated the prevalence rate of dermatological manifestations of arsenic poisoning at 2.8 per 1,000 (Ahmed and Ahmed, 2002). Recent extrapolations by BUET using USEPA models suggest that approximately 375,000 people in Bangladesh may develop various arsenic-related cancers (Ahmed and Ahmed, 2002).

Cancers have been detected among about 1 percent of persons identified with arsenicosis (Karim, 2000). A number of deaths resulting from arsenic-induced skin cancer have been reported in recent years (World Bank, 2000). As the symptoms of arsenic exposure take time to develop and as most of the country's tubewells have been installed over the last two decades, it is possible that many more people will show symptoms of arsenic toxicity in the coming years. According to estimates, unless exposure ends, the number of patients with arsenicosis in Bangladesh will eventually far exceed 200,000 (Smith et al. 2000: 1095).

1.3 The extent of arsenic contamination in Bangladesh

Arsenic-contaminated tubewells are spread across the country, and are concentrated in the south-west, south-east, and north-west regions. High levels of arsenic have been detected in 59 of the 64 districts of the country, and 249 of the 463 sub-districts. A map of the tested tubewells in Bangladesh by DPHE, reproduced in this report (see Map), indicates that there is a high degree of spatial variability across districts (UNICEF, 2000), with the proportion of contaminated tubewells ranging from 2 percent to 90 percent (BGS and MM, 2000). In districts where over 80 percent of the tubewells are contaminated and unsafe, there may be few alternatives to groundwater.

It is difficult to precisely estimate the level of arsenic contamination of tubewells as the majority of tubewells in Bangladesh have not been tested. Several surveys have reported high levels of arsenic concentration in water samples of tubewells. A study



Arsenic-affected areas in Bangladesh

of about 3,500 shallow tubewells, in 1998, found that 27 percent contained an arsenic level of more than 0.05 mg/l (the permissible standard in Bangladesh) (BGS, 2001). Similarly, 29 percent of the 51,000 tubewells tested by the Bangladesh DPHE in 1996-99 were found to have levels of arsenic above 0.05 mg/l (UNICEF, 2000).

In a significant proportion of cases, the arsenic levels in the water samples analyzed were found to be much above the standard of 0.05 mg/l. Of the 2,022 water samples from 41 districts of Bangladesh analyzed in the UK, under the BGS-Mott MacDonald study mentioned earlier, 51 percent were found to be above 0.01 mg/l (the WHO guideline value), 35 percent above 0.05 mg/l (the Bangladesh drinking water standard), 25 percent above 0.1 mg/l, 8.4 percent above 0.3 mg/l, and 0.1 percent above 1.0 mg/l (BGS and MM, 2000; Caldwell et al., 2003). The findings of the Rapid Action Program were similar — about 62 percent of the 32,651 tubewells surveyed in 200 arsenic-contaminated villages, in 1997, had arsenic concentrations above 0.1 mg/l (Smith et al., 2000:1095).

Based on these estimates, about 1.5-2 million of the 6-8 million shallow tubewells in Bangladesh may contain water with unsafe levels of arsenic contamination exposing between 30-40 million people to the risk of arsenic toxicity. This estimate is based on the recommended safe limit of the Government of Bangladesh. If the WHO recommendation of the safe limit of 0.01mg/l is adopted, the number of exposed persons would be much higher.

1.4 Quest for solutions

Given the magnitude of the problem of groundwater contamination facing Bangladesh, effective, acceptable, and sustainable solutions are urgently required. A number of bilateral and international agencies in the country are currently involved in research on water testing for arsenic and arsenic mitigation activities. NGOs are using their extensive rural networks to raise awareness and conduct pilot projects. Private companies are sponsoring research on arsenic removal units and testing their effectiveness.

Two studies are of interest here. A recent study of household-level arsenic removal technologies (BAMWSP, DFID, and WaterAid Bangladesh, 2001) assessed the effectiveness of selected arsenic removal technologies, and household satisfaction in operating these based on a specific set of criteria. Another study evaluated arsenic mitigation technologies in rural Bangladesh based on the experience of implementing an action research project in two *upazilas*[4] (BRAC, 2000). Both studies focused mainly on the technical performance of the arsenic mitigation technologies as discussed further in Chapter 2. However, limited information is available on people's preferences for arsenic mitigation technologies and whether they are willing to contribute to alternative methods and cost-sharing arrangements. Similarly, there is limited data on whether household-based arsenic removal technologies are preferred to the use of alternate arsenic-free sources, including piped water systems.

1.5 Objectives of the study

This report is based on the findings of a field study of households in rural Bangladesh. It seeks to analyze the demand for arsenic-free, safe drinking water based on the preferences of rural households for arsenic mitigation technologies and alternate safe water supply systems, including the option to access water from piped supply systems. It also assesses how much rural households are willing to pay for mitigation technologies and alternate safe water supply systems, possible cost-sharing arrangements, and related cross-subsidies.

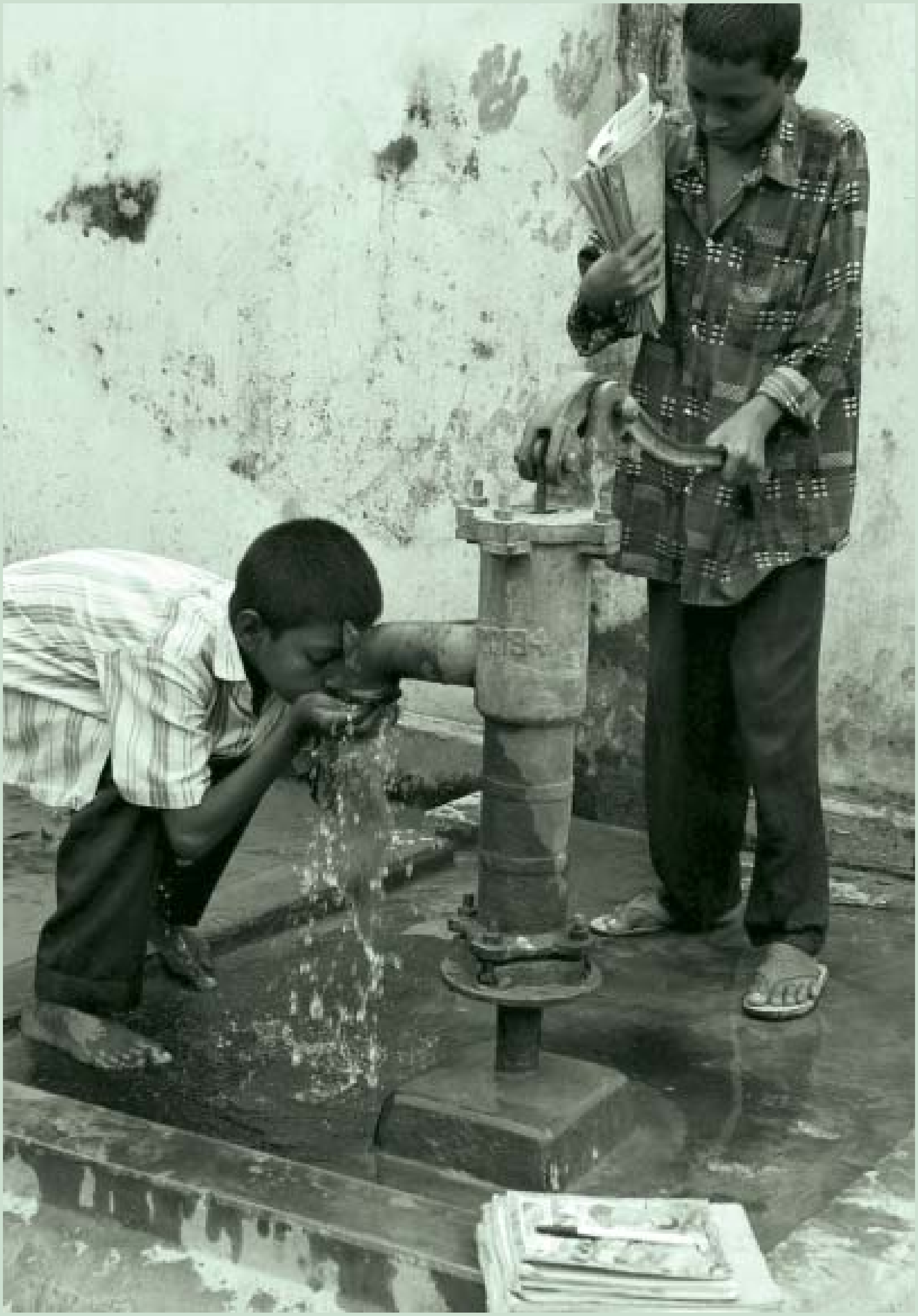
Data for the study were gathered through a carefully designed survey fielded among 2,880 rural households in three hydrogeologically representative districts of Bangladesh. This was supplemented by information from key representatives at the village level through questionnaire-based interviews.

The findings of the study are presented in the following chapters. Chapter 2 examines the safe water options available in Bangladesh. The study design and the sampling framework used for the survey are discussed in Chapter 3. Chapters 4-6 present the data gathered through the household surveys on the socio-economic profile of the respondents, the extent of awareness of the arsenic problem among households and the sources and uses of water in rural households. Issues such as shifts in sources of water for drinking and cooking in recent years, and the testing of tubewells for arsenic contamination are also discussed.

Chapters 7-10 cover the demand for arsenic-free, safe drinking water in rural areas, household preferences and their willingness to pay for arsenic mitigation technologies and alternate safe water supply systems. Chapter 7 assesses people's preferences among arsenic mitigation technologies, while Chapter 8 examines people's preferences for piped water supply systems. Chapter 9 explores whether households prefer piped water supply or other arsenic mitigation technologies. Chapter 10 deals with people's preferences for piped water supply in arsenic-affected areas where there has been a large-scale shift to public tubewells.

The main findings of the study are discussed and recommendations for policy suggested in Chapter 11. The annexures include the sampling strategy used for the administration and management of the field survey, the econometric methodology applied for the estimation of willingness to pay, estimates of the cost of piped water supply in rural Bangladesh used to analyze issues related to cost recovery of piped water supply systems (see Chapters 8 and 10), and details of computation of the value of arsenic-free water by the revealed preference method.

[4] An *upazila* is a sub-district.



2 Alternate Safe Water Options

In the context of the large-scale contamination of tubewells with arsenic in Bangladesh, an immediate concern is to provide safe water free from arsenic as well as other chemical and bacteriological contamination. However, the technology that is promoted to provide safe water should have features that are desirable in any water supply system. The technology should provide an adequate supply of water throughout the year, be safe to operate, convenient to use, acceptable, and robust. An important related issue is whether households have the competence to operate and maintain the technology. This chapter discusses available safe water options in Bangladesh and presents a review of two recent studies that have evaluated arsenic mitigation technologies.

2.1 Arsenic mitigation technologies

In areas where drinking water contains unsafe levels of arsenic, the main options to provide safe water are either to remove arsenic from the contaminated source or to find a new safe source of water supply (Johnston and Heijnen, 2001; WSP-SA, 2000:3). The options have been discussed below in detail.

2.1.1 Removing arsenic from existing contaminated sources of water

Most technologies for arsenic removal make use of several processes either at the same time or in sequence, and have the advantage of removing other undesirable compounds as well.

Several methods can be used to treat water and make it arsenic-free (Ahmed, 2001; Johnston and Heijnen, 2001; Mudgal, 2000). These include:

- Oxidation and stripping
- Coagulation, precipitation, and filtering using iron and aluminium salts
- Lime softening
- Ion exchange
- Membrane process (reverse osmosis)
- Adsorption on activated alumina/ activated carbon/ activated bauxite/ ferric hydroxide

The three major factors to be considered when choosing an arsenic removal treatment system are the cost, reliability, and ease of O&M of the technology.

Based on these considerations, the processes of coagulation, precipitation and filtering,[5] and adsorption[6] are regarded as relatively more suitable for rural households than the other methods listed above.

The membrane process and ion exchange are generally not suitable for rural households because the cost is high and the technical requirements are hard to meet (Mudgal, 2000). Reverse osmosis, for example, requires a special membrane and water to pass through the filter under high pressure, which may not be practical in rural households. The ion exchange process is uneconomic if the total dissolved solid is more than 500 mg/l, which is common in groundwater (Mudgal, 2000).

The oxidation and stripping method is relatively simpler to implement. However, this method is often ineffective in reducing arsenic concentration to the desired level. For example, passive sedimentation (which involves putting water in a bucket, stirring so as to allow air oxidation, and then letting the water settle for about 12 hours) is a simple method to remove arsenic in rural areas. However, studies have shown that this method is not effective in reducing arsenic to the desired level (Ahmed, 2001; Khan et al., 2000; WSP-SA, 2000:7).

The lime softening process leads to high pH levels, which need to be readjusted. Moreover, a large volume of waste is generated. Compared to coagulation with iron salts or alum, lime softening is more expensive (Johnston and Heijnen, 2001).

2.1.2 Source substitution or developing and delivering alternative arsenic-free water sources

Three main sources of water can be considered as substitutes for arsenic-contaminated shallow tubewell water: groundwater in deeper aquifers, rainwater, and surface water. Two other options are dugwells and piped water supply (Ahmed and Ahmed, 2002; BRAC, 2000; WSP-SA, 2000).

Groundwater in deeper aquifers (below 150 to 200 meters) is generally free of arsenic (Ahmed and Ahmed, 2002) and can be used as an alternate source of water, to be drawn with the help of deep tubewells (UNICEF, 2000). Surface water from ponds or rivers can be boiled or filtered at home to remove bacteriological contamination. For use at the community level, serving 40-60 families or more, pond sand filters can be used to filter water from ponds that are reserved exclusively for drinking purposes (Ahmed and Ahmed, 2002; BRAC, 2000; Rahman, 2001; UNICEF, 2000).[7]

Rainwater can also be a source of water supply. A tin roof or a plastic sheet can be used to collect rainwater, which is then stored in a large cement tank. Rainwater is free from arsenic and bacteriological contamination. These harvesting systems can be successfully used in areas where rainfall is adequate throughout the year. However, the water harvested through these systems is susceptible to bacteriological contamination during the process of collection and storage, and may require some form of treatment (Adeel and Ali, 2002).

Dugwells are 25 to 30 feet deep. Although high arsenic levels may be present in shallow aquifers (which are 20 to 40 meters below the ground), ultra-shallow aquifers (1-10 meters deep) generally have a low concentration of arsenic (BRAC, 2000:61). Dugwell water is safe from arsenic because the oxidation process, water's exposure to open air, and agitation during withdrawal can cause precipitation of dissolved arsenic and iron. A major problem with dugwells is that while the water is arsenic-free it may not be safe because it is very difficult to protect it from bacteriological contamination. The problem can be addressed by lining the dugwell with concrete and protecting it (using a handpump to lift the water and

[5] In the precipitation process, dissolved arsenic is made to form a low-solubility solid mineral, which is then removed through sedimentation and filtration. When coagulants are added and form flocs, other dissolved compounds such as arsenic become insoluble and form solids. This is known as coprecipitation. The solids formed require removal through solid/liquid separation processes (see Johnston and Heijnen, 2001).

[6] Various solid materials, including iron and aluminum hydroxide flocs, have a strong affinity to dissolved arsenic. Arsenic is strongly attached to the sorption sites of these solids, and is effectively removed from the solution. This is the adsorption process for arsenic removal (see Johnston and Heijnen, 2001).

[7] Water is purified in a pond sand filter in two stages: through a horizontal roughing filter and a slow sand filter. Instead of a roughing filter, pond water can be pre-treated using other methods such as by adding alum, followed by coagulation and settling (BRAC, 2000).

covering the top), which will ensure water of acceptable quality (BRAC, 2000; Rahman, 2001).

A piped water supply system can be based on surface water or groundwater. It has the advantage of treating arsenic and other impurities at a centralized point. Moreover, since piped water is protected from external contamination, quality control can be ensured at the point of both treatment and delivery. Piped water supply is a feasible option for arsenic mitigation in urban centers, urban fringe areas, and clustered rural settlements. However, for scattered settlements in rural areas, it may be a costly option (Ahmed and Ahmed, 2002).

Box 2.1

Well-switching as a means of mitigating the current arsenic crisis in Bangladesh

Studies suggest that well-switching (where households move from using contaminated tubewells to safe tubewells in the neighborhood) could be a viable option to reduce the incidence of arsenic exposure in Bangladesh. Caldwell et al. (2003) argue that households encountering an arsenic problem in their tubewells should be encouraged to shift to safe tubewells in the neighborhood, rather than an alternate source (or install equipment for treating the contaminated water from their own tubewells). This would require a comprehensive national water-testing program for tubewells.

Even though the current program to test and identify arsenic-contaminated tubewells in Bangladesh and to paint them red or green depending on the results, implicitly encourages well-switching, the success of these efforts, however, depends on effective screening methods and a credible on-going monitoring mechanism, neither of which are in place.

There are also significant socio-economic barriers to switching wells as most wells are privately owned and there may be reluctance to share the water source. Privacy is another issue, since tubewells are usually installed near household latrines. Moreover, women, who traditionally collect water, are not usually allowed to leave their immediate household unaccompanied. Another point to consider is that if the density of users at each well increases, this may affect the aquifer and the water source may, in turn, become arsenic-contaminated.

2.2 The situation in Bangladesh

2.2.1 Arsenic removal technologies

A number of arsenic removal technologies have been field-tested in Bangladesh (Ahmed, 2001; Ahmed and Ahmed, 2002; BRAC, 2000; Mudgal, 2000; WSP-SA, 2000). These include the two-bucket treatment unit (2BTU) promoted by DANIDA and DPHE, Safi filter, three-*kolshi*[8] filter unit, BUET activated alumina, and Alcan enhanced activated alumina. These units use the processes of coagulation and precipitation, and adsorption to remove arsenic. Other technologies based on the adsorption process that have been field-tested are arsenic removal units based on granular ferric hydroxide promoted by Pal Trockner (P) Ltd, India and Sidko Ltd, Bangladesh, and Read-F promoted by Shin Nihon Salt Co Ltd. A technology based on the ion exchange method tested in Bangladesh is the Tetrahedron ion exchange resin filter.

Arsenic removal technologies in Bangladesh have attracted greater attention than the option to provide an alternate arsenic-free water supply. This is because of the perception that to provide additional community water facilities, such as dugwells, deep tubewells, or pond sand filters, would require huge investments and considerable time to set up. Arsenic removal technologies, in contrast, are considered a cheap and quick method to mitigate arsenic because they allow households to continue using existing sources of water such as shallow tubewells, and no additional investment is required to set up these new facilities (WSP-SA, 2000).

While arsenic removal technologies clearly provide practical short-term solutions, particularly in areas where arsenic contamination is high, the effectiveness of these

[8] A *kolshi* is a pitcher.

technologies in the long run depends critically on the ability of local communities to accept, operate, and maintain the technologies/equipment. As all arsenic removal technologies generate some arsenic-rich waste, the safe disposal of toxic sludge from these treatment units is another crucial issue. In a number of household and community-based units, the sludge contains a high concentration of arsenic, but currently no solutions are being offered to manage its safe disposal.

It may be mentioned here that the technology to treat water for arsenic at the household or community level is still being developed and tested. Although a number of options have been designed for use at these levels, they are limited in their effectiveness. The equipment does not always result in lowering the level of arsenic in the water to safe levels after treatment, and some technologies (the three-*kolshi* method) are susceptible to bacteriological contamination (BAMWSP, DFID, and WaterAid Bangladesh, 2001; BRAC, 2000; Mudgal, 2000; WSP-SA, 2000; see also Adeel and Ali, 2002; Ahmed, 2001; Ahmed and Ahmed, 2002). Moreover, issues such as convenience, the establishment of supply chains for chemicals to keep the equipment functioning, and affordability could also inhibit the use of such technologies on a large scale.

Box 2.2

Arsenic contamination of groundwater in Bangladesh

Only shallow aquifers appear to be contaminated with arsenic in Bangladesh. Most deep aquifers, in contrast, are free from arsenic contamination. A study by Chakraborti et al. (1999) reveals that there is virtually no arsenic contamination in tubewells deeper than 300 meters and only a few tubewells deeper than 100 meters are contaminated. A hydrological survey by the British Geological Society reported similar findings. Out of 1,662 wells less than 100 meters deep, over 40 percent exceeded the Bangladesh drinking water standard of 0.05 mg/l, and out of the 317 wells observed that were deeper than 150 meters, less than 1 percent exceeded the Bangladesh standard (BGS and MM, 2000).

A major limitation of arsenic removal units is that they are inconvenient to use. Units based on adsorption, for instance, need periodic regeneration by washing, the filter media needs to be changed periodically, and the waste has to be disposed of. In some technologies (the three-*kolshi* method), the wait to get treated water is long as the rate of water flow is low.

2.2.2 Source substitution

With the large-scale contamination of shallow tubewells in Bangladesh, there is an immediate need to promote alternative sources of water supply. Possible alternative sources include deep tubewells, dugwells, rainwater harvesting systems, and surface water facilities, which are currently being promoted under arsenic mitigation programs (BRAC, 2000; UNICEF, 2000). However, these technologies have their limitations. It may be difficult to ensure that the water is free from bacterial contamination, particularly when sourcing water from surface facilities. Water from dugwells is also susceptible to bacteriological contamination. Methods such as rainwater harvesting may not provide an adequate quantity of water to meet annual demand due to the prolonged dry season.

Deep tubewells are a promising safe water option in Bangladesh, but they have the following two drawbacks:

- It may be difficult to drill deep aquifers in some areas because of unfavorable geological conditions.
- The water may be unsuitable for drinking because of salinity, for example, in the coastal belt, south of Bangladesh.

Arsenic contamination may be on the rise in Bangladesh. While deep aquifers are currently safe from arsenic, there is a growing concern that these aquifers may get cross-contaminated by arsenic seeping from shallow aquifers (Adeel and Ali, 2002). The extent of arsenic contamination in the shallow aquifers may also be increasing as many tubewells that had initially been found to be safe after testing were later found to be contaminated with arsenic (Chakraborti, 1999; Chakraborti et al., 1999).

2.3 Assessment of arsenic mitigation technologies: A review of two evaluation studies

Two studies have recently been completed to assess the performance and acceptability of a range of arsenic removal technologies in Bangladesh. A rapid assessment of household-level arsenic removal technologies was conducted, supported by BAMWSP, DFID, and WaterAid, Bangladesh. The project evaluated nine available user-friendly technologies in two phases (BAMWSP, DFID, and WaterAid Bangladesh, 2001).[9] In the first phase, seven technologies were found to consistently reduce arsenic to an acceptable level of 0.05 mg/l. The seven technologies are Alcan enhanced activated alumina filter, BUET activated alumina filter, DPHE/DANIDA two-bucket system, Garnet homemade filter, Sono three-*kolshi* method, Stevens Institute Technology, and Tetrahedron ion exchange resin filter. The other two technologies, considered in the first phase of the study, passive sedimentation and Adarsha filter, were not found to be effective in reducing arsenic.

After establishing the effectiveness of the seven technologies in reducing arsenic to the desired level, in the second phase of the study these technologies were further evaluated for their technical performance and social acceptability. The study found that the performance of the technologies varied. The Alcan, BUET, and Sono three-*kolshi* method were found to consistently reduce arsenic to below 0.05 mg/l.[10] The Stevens Institute Technology and Tetrahedron ion exchange filter effectively reduced the level of arsenic to below 0.05 mg/l in most cases. Use of these five technologies did not result in an increase of other significant parameters (such as the level of manganese and aluminium) above the permissible drinking water standards recommended by the Bangladesh Government and WHO. The DPHE/DANIDA two-bucket system proved ineffective when the feed water contained arsenic above 0.12 mg/l. Further, the level of manganese and aluminium in water treated by this technology occasionally exceeded the Bangladesh drinking water standard. The technical performance of the Garnet homemade filter was found to be erratic. In one area (Iswardi), 66 percent of the treated water samples had arsenic below 0.05 mg/l, whereas in another area (Hajiganj) only 8 percent of the treated water samples had arsenic below 0.05 mg/l.

Some technologies were not effective in eliminating bacterial pathogens. While the Tetrahedron and Stevens Institute Technology, which include a process of chlorination, reduced the presence of microorganisms, the Alcan, BUET and Sono three-*kolshi* technologies were found to be susceptible to bacteriological contamination. The results of the Alcan and Sono three-*kolshi* methods were by and large in keeping with the findings of the BRAC study discussed later in this chapter.

Economic status was found to be a key factor determining acceptability and the price that households were willing to pay for arsenic removal technologies. Although most households showed a preference for the features of the more expensive technology, namely Alcan, very few could realistically afford this technology individually.

The most acceptable of the seven technologies considered in the second phase of the study were Alcan, Tetrahedron, Sono, and Stevens. The BUET activated alumina unit was found to be effective in reducing arsenic and did not result in any water chemistry problems. However, it was the least preferred by the households among the technologies considered because it was too tall and unstable making it difficult to use and maintain, the water flow rate was low, and the treated water did not taste good and had a smell.

The study suggests that implementing agencies should promote technologies that are effective and socially acceptable, such as Alcan enhanced activated

[9] For a review of the study, see Sutherland et al. (2001).
[10] BRAC (2000) and Khan et al. (2000) also found that the three-pitcher method can effectively remove arsenic.

alumina, Tetrahedron, Sono three-*kolshi* and Stevens, on a larger scale. Even though the microbiological results of treated water are alarming, promotional programs should not be delayed. Rather, extensive microbiological testing should be carried out after the technologies are introduced. These technologies should be provided financial support, particularly the more expensive but effective and robust ones, for example, Alcan.

A study by BRAC evaluated arsenic mitigation technologies in rural Bangladesh (BRAC, 2000). The study is based on its experiences in implementing an action research project in Sonargaon and Jhikargachha *upazila*s in 1999-2000. Technologies covering both source substitution and arsenic removal were assessed in the study. The technologies evaluated were the treatment of surface water with pond sand filters and home-based filters, rainwater harvesting, treatment of arsenic-contaminated groundwater with the home-based three-*kolshi* filter, Safi filter, activated alumina filter, SKIDO plant and the tubewell sand filter, and the use of shallow groundwater through dugwells. The options were assessed on the following criteria: capital and running cost, ease of implementation, operation and maintenance, continuity and flow of water supply, capacity to remove arsenic, susceptibility to bacteriological contamination, and acceptability within the community.

The three-*kolshi* filter was reportedly the most popular and practical in the short-run due to its low capital and operating cost, ease of operation, and availability of material to make the filter. The other potential technologies identified by the project were the activated alumina filter and tubewell sand filter (which is essentially a larger version of the three-*kolshi* method). Rainwater harvesting was a less preferred option as it provides safe water for only a part of the year and the cost of constructing a harvesting system is high. As this option is only a partial solution, households were not willing to bear the high capital cost of setting up such systems.

Among the community-based options, the pond sand filter initially created an interest but it was later found that households were keen to use the treated water for cooking rather than drinking. This is mainly because they did not like the taste of filtered pond water, which is very different from the taste of tubewell water they are accustomed to.

While the studies reviewed in this chapter are optimistic about the possibility of successfully promoting the use of household and community-based arsenic removal units on a large scale, field observations and feedback from the program staff suggest that this may not be an effective option. Although a number of household arsenic removal units have been distributed, only a few are actually being used. It has also been suggested that although various arsenic removal technologies are being field tested by BAMWSP, "the high iron content of the water in the test area causes continual clogging of the filters, and a combination of inadequate backwashing facilities, a lack of ownership, and the availability of alternative water sources nearby, has resulted in most of the test units being abandoned within the first month of use" (WSP-SA, 2000:7).

Acceptance of arsenic mitigation technologies among rural communities is governed not only by the effectiveness, cost, and convenience of the technologies. Acceptance also depends on how strongly motivated households are to find solutions to the arsenic problem. Awareness about the health hazards and high-risk perception can motivate households to adopt arsenic mitigation technologies. Jakariya (2000) has studied the adoption of safe water options in two arsenic-affected villages, Vhagolpur in Sonargaon *upazila* and Kamarpara in Jhikargachi *upazila*. His study highlights the link between awareness of arsenic exposure as a health hazard and the adoption of a safer source of water. In these villages, over 90 percent of the tubewells tested were arsenic-contaminated. Although most people felt that arsenic-contaminated water was a major problem and were aware of safe water options, yet 80 percent of the people of Vhagolpur continued to drink arsenic-contaminated water. In Kamarpara, in contrast, only 14 percent of the residents had not changed their source of water supply.

This difference can perhaps be understood in terms of the incidence of arsenicosis in the two villages. While Kamarpara had 40 identified arsenicosis cases, Vhagolpur had none. The study concludes that households in Vhagolpur were reluctant to shift to safe water options due the age-old practice of drinking tubewell water without any difficulty and the absence of any case of arsenicosis. Better nutritional conditions, the long incubation period of the disease, and the cumbersome process of obtaining water from alternative safe options were other reasons for their reluctance.

In Kamarpura, in contrast, awareness of the health effects of arsenic exposure and the relatively higher incidence of arsenicosis had motivated most people to stop using contaminated tubewells and shift to safe water options. It should be noted that though households were initially using the safe water options provided by BRAC under its mitigation program implemented in the village, these were abandoned when the government introduced deep tubewells in the village. The fact that villagers living at a distance from deep tubewells continued to drink arsenic-contaminated water in spite of the presence of a number of arsenicosis patients in the village indicates that convenience is an important factor influencing the decision to adopt safe water options. These households had not even opted for safe water options such as the three-*kolshi* method. It appears that the inconvenience associated with accessing water from alternative safe options vis-à-vis the use of tubewells directly has been a crucial factor influencing their behavior.

2.4 Is piped water supply a viable option?

Most assessments of safe water options have not explored the option of piped water supply as a possible solution. Rather, the focus has been on household or community-based arsenic removal units that treat tubewell water to make it suitable for drinking despite the limitations of these technologies and the danger of bacteriological contamination.

The BRAC study did not include piped water supply among the arsenic mitigation technologies reviewed, although it has recognized the effectiveness of piped water supply systems as a possible long-term solution to the arsenic problem. According to the study: “It is clear that the technologies introduced in the project to supply arsenic-free safe drinking water are only short-term emergency solutions for areas severely affected by arsenic contamination. The longer-term solutions must be based on a long-term vision. This may include the provision of piped water supply to its population and the optimum use of surface water.” (BRAC, 2000: 87).

As mentioned in the earlier discussion, a major disadvantage of arsenic removal units is that they are inconvenient to use. This is one reason (if not the main reason) why, after initial installation, these units have fallen into disuse. It is now increasingly being felt that piped water could be a long-term solution to the arsenic problem.

Piped water supply has the advantage of convenience of collection and use, and can compete with the existing system of tubewell water supply (Ahmed and Ahmed, 2002:140). People may opt for piped water supply mainly for the convenience it offers (if the cost is not prohibitive); the fact that it also addresses the arsenic problem would be viewed as an added advantage. Piped water supply can also address other problems of water quality (salinity is a problem in some areas) and quantity. At a workshop in Bangladesh,[11] water supply experts suggested that for arsenic mitigation piped water supply should be the eventual objective, and that other options should be promoted keeping in view local conditions (Adeel and Ali, 2002; Ahmed and Ahmed, 2002).

[11] International Workshop on Arsenic Mitigation in Bangladesh, January 14-16, 2002, Ministry of Local Government, Rural Development and Cooperative, Government of Bangladesh.

3 Study Design and Sampling Framework

Measuring people's preferences for non-market commodities, such as an improvement in the quality of the environment, poses significant methodological challenges. The challenges were far greater for this study on the demand for safe arsenic-free drinking water (a non-market commodity) in rural Bangladesh. This is because multiple options are available for obtaining safe arsenic-free drinking water, and it was necessary to incorporate this choice into the analysis. Moreover, a suitable methodology was required to estimate the value of arsenic-free drinking water to the rural people.

The field study discussed in this report (hereafter referred to as the Bangladesh study) used a detailed survey to assess the demand for safe drinking water options in rural areas and evaluate people's perceptions of available arsenic mitigation technologies[12] (other than piped water) and piped water supply systems. A contingent valuation methodology was used to assess the demand for piped water in rural areas and establish the extent to which people would be willing to share the cost of setting up an alternate safe piped water supply system. The survey data helped to ascertain people's choices among arsenic mitigation technologies, their inclination for piped water supply systems, and the preferred option between piped water and other arsenic mitigation technologies.

Rural households in three districts of the country were surveyed. To ensure that responses were representative, people were interviewed in arsenic-affected areas, arsenic-free areas, and areas where there had been a large-scale shift from arsenic-contaminated sources to arsenic-free supply. By including arsenic-free areas in the survey, it was possible to compare the demand for piped water in arsenic-affected areas with that in arsenic-free areas, and thus derive an estimate of the arsenic-free component out of the total value of piped water to the rural people. This chapter discusses the methodology

[12] Arsenic mitigation technologies are defined as technologies that enable people in arsenic-affected areas to access arsenic-free water. These include both arsenic removal technologies (or arsenic treatment technologies) and alternate arsenic-safe water sources, such as deep tubewells and pond sand filters. Piped water basically belongs to the latter category of arsenic mitigation technologies. However, throughout the study, this option will be considered separate from other arsenic-free water sources. Accordingly, arsenic mitigation technologies will be used to refer to arsenic removal technologies and alternate arsenic-safe water sources, except piped water which is considered as a separate option.

used in the study, the study design, the sampling framework, and the survey instruments (questionnaires) used to gather information.

3.1 Use of contingent valuation methodology to assess preferences and estimate willingness to pay

Contingent valuation is the most widely used method to estimate consumer preferences for non-market commodities that do not have a well-defined market price (see, for instance, Mitchell and Carson, 1989). Through contingent valuation surveys, people are asked to state their preferences for a public good, contingent on a specific hypothetical scenario and description of the good. Economic values are derived from the choices observed in the hypothetical market created in the survey.

The accuracy of the results obtained from a contingent valuation survey is critically dependent on the design of the questionnaire and administration of the survey.[13] For the contingent valuation survey to yield accurate results, the good to be valued has to be clearly explained, its delivery to the public appear possible, and an expectation of realistic payment created (Carson et al., 2001). The payment mechanism must be credible so that the respondents believe that they actually could have to pay for the good.

It is also essential that the questionnaire design, particularly the value elicitation format, minimizes bias in the responses and ensures an accurate revelation of preferences. Strategic behavior on the part of respondents (either systematically overstating or understating their willingness to pay) can seriously distort the results of a contingent valuation survey. To curb such strategic bias, a dichotomous choice question format (or multinomial choice question format for situations where there are more than two alternatives to choose from) is better than an open-ended question format (Carson et al., 2001; Mitchell, 2002). For the administration of the survey, in-person interviews are considered more appropriate than mail surveys as respondents who return the mail surveys tend to be more interested in the good than the non-respondent (Carson et al., 2001). In-person interviews generally reduce the likelihood of biases in sample selection and provide more control on the order and manner in which survey material, including visual aids, are presented to the respondent.

Given that the responses obtained in a contingent valuation survey could be subject to various kinds of biases, it is important that the contingent valuation responses are validated. There are different approaches to determine the validity of contingent valuation responses; two common approaches are construct validity and convergent validity (Carson et al., 2001; Garrod and Willis, 1999). Construct validity refers to how well the measurement is predicted by factors that would be predictive *a priori*. Most contingent valuation studies present an econometrically estimated equation that relates the respondent's willingness to pay to the respondent's characteristics and to the characteristics of the good to be valued. This can be used to check whether the willingness to pay found in the contingent valuation survey is consistent with economic theory (one would expect the proportion of the consumers willing to pay a particular price for the good to decline as the price is raised, and the willingness to pay to increase for a larger amount of the desired good).

Convergent validity of contingent valuation responses can take different forms. A common form applied in many studies is to compare the contingent valuation estimates with those obtained by other methods (for instance, the revealed preference method) (Carson et al., 2001). It must be noted, however, that both the contingent valuation and revealed preference estimates have their own limitations, and the latter estimates should not be used only as a criterion against which the contingent valuation estimates are to be judged (Whittington and Swarna, 1994).

[13] For discussion on contingent valuation method, see, for instance, Bjornstad and Khan (1996), Carson et al. (2001), Garrod and Willis (1999), Mitchell (2002), and Mitchell and Carson (1989).

Table 3.1: Key steps in the study design

Design of the questionnaire on willingness to pay

- A meaningful and realistic questionnaire was designed to assess household willingness to pay for arsenic-free, safe drinking water.
- Biases normally associated with such a survey were minimized.
- Validity checks to cross-check willingness to pay values were especially designed using revealed preference criteria.
- The draft questionnaire was externally reviewed.
- The questionnaire was presented at WSP-SA and BRAC (R&D) and finalized.

Pre-testing the survey and training enumerators

Testing the questionnaire in the field

- A draft questionnaire was pre-tested in three hydrogeologically representative locations to ensure that the hypothetical scenario was plausible.

Training enumerators

- About 45 enumerators were specially trained to conduct the survey.

Fielding the survey

- A survey was conducted in three hydrogeologically representative districts with arsenic contamination. In each district, three severely affected *thanas* were identified for the survey.
- A stratified random sampling methodology was used to select five villages in each identified *thana*, and 53-55 households in each village.
- About 800 households were surveyed in the arsenic-affected areas in each district (totaling to 2,430 households) and 300 households were surveyed in an arsenic-free, control area.
- In addition, 150 households were surveyed in an arsenic-affected area where there has been a large-scale shift to arsenic-free water sources. This component of the survey was done in five randomly selected villages in one *thana* of Barisal district, and 30 households randomly selected from each village.
- In all, 2,880 households were surveyed.

Analyzing the data

- Econometric methodology (a multinomial logit model) was used to analyze the data and derive estimates of willingness to pay.
- Relevant and statistically significant explanatory variables were identified.
- Preliminary results on willingness to pay were presented at WSP-SA and comments/ suggestions incorporated to prepare the draft report.
- The draft report was reviewed by an expert on contingent valuation methodology before finalization.

A number of studies of rural water supply in developing countries have used contingent valuation surveys to assess people's willingness to pay for improved water supply (see, for instance, Altaf et al., 1992 for Punjab, Pakistan; Briscoe et al., 1990 for Brazil; Singh et al., 1993 for Kerala, India; and Whittington et al., 1990 for Haiti; for a review of the literature, see World Bank Water Demand Research Team, 1993). A recent contingent valuation study on willingness to pay for improved water supply in the context of a developing country is by Pattanayak et al. (2002) for Kathmandu Valley, Nepal.

Box 3.1

What is contingent valuation?

The contingent valuation method is used to elicit people's preferences when markets are absent, imperfect, or incomplete. It is most commonly used for the valuation of public goods and, in particular, for the quantification of benefits from an improvement in the quality of the environment. It offers a direct, intuitively appealing means to estimate the economic benefits of a public good. Rather than attempting to infer the value that an individual places on the public good from behavioral information, one simply asks directly as to how much the individual or the household would be willing to pay for the good. The technique derives its name from the fact that the value estimates are contingent on a hypothetical scenario that is presented to the respondents for valuation.

The contingent valuation method is also known as the stated preference method, or the direct approach because people are directly asked to state or reveal their preferences. The other possible approach to valuate is to infer the preferences or values from actual behavior (how much people pay for houses [the hedonic price method], or travel to an environmental amenity [the travel cost method]), referred to as the revealed preference approach, surrogate market approach, or indirect approach.

Contingent valuation methodology has been used in this study to assess the demand for arsenic-free safe drinking water, and examine people's preferences regarding piped water supply systems and household/community-based arsenic mitigation technologies. The willingness to pay for piped water systems through standposts and domestic connections has also been analyzed.

While applying the contingent valuation methodology in the study, care was taken in both designing the questionnaire and administration of the survey (for details, see Section 3.3).

3.2 Study design

The field survey for the Bangladesh study was conducted from October to December 2001. A total of 2,880 randomly chosen households were surveyed in Chandpur district (a high water-table area), Chapai Nawabganj district (a low water-table area), and Barisal district (a coastal area). In all, 2,430 households were selected from the arsenic-affected areas (about 800 from each district) and 300 households were chosen from the areas not affected by arsenic (150 from Bolarhat *thana*[14] of Chapai Nawabganj district and 150 from Commilla Sadar *thana* of Commilla district).[15] In addition, 150 households were surveyed from Banaripara *thana* in Barisal district, an arsenic-affected area where a marked shift to public tubewells has taken place (see Table 4.1). The areas surveyed are hydrogeologically representative, and reflect the water sources available, the current level of water consumption, and aspects of convenience in accessing water (for details of the sampling methodology, see Annex A).

Prior to fielding the survey, household and village-level questionnaires were designed to specifically assess the willingness to pay for arsenic-free safe

[14] A *thana* is an administrative unit under a sub-district.

[15] An arsenic-free *thana* could not be found in Chandpur district for the survey. So a *thana* was chosen from Commilla, an adjacent district.

drinking water in rural Bangladesh, keeping in mind the need to control biases that are normally associated with such surveys. Following a series of reviews and validity checks, the draft questionnaire was pre-tested in the three districts. Enumerators were also trained to conduct the survey. The surveys were then fielded by BRAC. Responses were collated and analyzed using appropriate econometric methods. Details are discussed in the following sections. Table 3.1 outlines the key steps involved in the design of the study.

3.2.1 Focus group discussions, pre-testing the questionnaire, and training enumerators

The most critical aspect of a contingent valuation study is the design of the survey instrument (questionnaire). To ensure that meaningful, realistic, and plausible scenarios were constructed, focus group discussions were held in some rural areas before the preliminary questionnaire was designed. The draft questionnaire was pre-tested in villages of the three districts covered in the study and refined. The questionnaire was revised after three rounds of pre-testing and discussion and feedback from WSP-SA. After final revisions, the questionnaire was translated into the local language and pre-tested once again before being fielded. This process of designing and pre-testing the questionnaire took about six months.

Contingent valuation experts and BRAC representatives trained about 45 field staff to conduct the survey. Training was conducted at the BRAC office and in the field. Each enumerator was required to fill five questionnaires to ensure that he had understood the methodology and the questionnaire before being selected for the survey. About 30 enumerators were finally selected.

3.2.2 Design of the questionnaire

3.2.2.1 Household survey

The household survey was designed to gather detailed information on key characteristics of the respondents, their preferences and choice of technologies. The main sections of the survey are listed here along with details of the information that was gathered in each section.

Key information on the respondent. Details about age, sex, education, and occupation of the respondent, education and occupation of the household head, the relationship of the respondent with the household head, and total number of family members were sought.

Water use and sources. The pattern of water use in the household in the dry/wet season and the main sources of water for drinking, cooking and washing, household satisfaction with the current available quantity of water and problems related to quality were the particulars the field staff looked into. Information about the incidence of diarrhoea in the household in the two weeks preceding the survey and in the previous six months, medical expenses and human-days lost due to the occurrence of the disease, and what according to the respondent was the cause of infection was also gathered.

Perception of the arsenic problem. Whether respondents were aware of the problem of arsenic contamination, their source of information, if they knew of anyone with arsenicosis, their understanding of the symptoms of arsenicosis in the short term and with prolonged exposure. Whether the respondents knew that in the advanced stages, arsenicosis could result in gangrene or cancer or even death. Affordability of medical treatment for arsenicosis, especially after it reaches an advanced stage, and households' perception of risk from arsenic-contaminated tubewells in the context of its impact on the health of the family and the cost of treatment.

Respondents were informed about the risks to health and the associated cost of medical treatment using specially designed cards (Box 3.2).

Changes in the source of water for drinking and cooking. Changes in water sources for drinking and cooking and reasons for the change, distance from the new source, the time spent collecting water, and whether water was treated to make it suitable for drinking were noted by the field staffers.

Testing of tubewells. The staffers enquired about whether the tubewell nearest to the respondent's house had been tested for arsenic contamination, was it found to be contaminated with arsenic, was the household using a tubewell known to be contaminated, and if so why had they not shifted to a safe water source.

Arsenic mitigation technologies. People's preferences regarding the six arsenic mitigation technologies selected for this study [three-*kolshi*, activated alumina (household based), activated alumina (community based), dugwell, pond sand filter, and deep tubewell], and which technologies they would rank first and second in order of preference. Problems encountered by households who had used or were using these technologies.

Information on the cost of each technology (one-time capital cost and annual O&M cost), and the advantages and disadvantages of each technology was provided through specially designed cards (see Box 3.2).

Other issues covered in this section were respondents' willingness to pay for and use one or more of the six selected arsenic mitigation technologies, reasons for unwillingness to pay in respect of the respondents who expressed their unwillingness, and the impact of subsidy on initial capital cost on the affordability of the technologies.

Piped water supply schemes. The option of a piped water system as an alternate long-term solution to the arsenic problem was introduced in this section. Information was obtained from the respondents on their preference for piped water based on the advantages/disadvantages of piped water systems. A specially designed scenario was used to assess cash/labor contributions (willingness to pay) for standposts/domestic connections. A closed-ended referendum question format (Box 3.3) was used along with split sampling (sample villages in a district were divided into five groups and five different levels of charges for piped water supply were quoted in the five sub-samples, with the respondents being given the option of using a public standpost or a domestic pipe water connection). The closed-ended question was followed by an open-ended question to assess the maximum willingness to pay for the piped water facility.

Choice between arsenic mitigation technologies and piped water supply schemes. Respondents were asked to choose between piped water supply

Box 3.2

Briefing cards used in the survey

Card 1: Symptoms of arsenicosis: Contains pictures and a description of the symptoms of arsenicosis.

Card 2: Health risks and the cost of arsenicosis treatment: Provides information on the three stages of arsenicosis (melanosis, keratosis, and cancer) and the estimated cost of treatment. It is pointed out that once arsenicosis reaches a highly advanced stage, it cannot be cured by medical treatment.

Card 2 (H): Health risks: Gives an indication of the risk of developing cancer by consuming arsenic-contaminated water.

Cards 3-8: Arsenic mitigation technologies: Separate cards for each of the six selected technologies for the study — three-*kolshi*, activated alumina (household-based), activated alumina (community-based), dugwell, pond sand filter, and deep tubewell (handpump). Each card has a photograph of the technology along with information about the cost, water availability per day, the number of families who will share the equipment or water source, and the main advantages and disadvantages of the technology.

Card 9: Summary information on the six technologies: Presents a comparison of arsenic mitigation technologies to facilitate ranking by the respondent. It provides a tabulated summary of the information contained in Cards 3 to 8 along with photographs.

Card 10: Piped water supply: Contains photographs to describe piped water supply schemes to the respondent, that is, public standposts and domestic connections.

Card 11: Important items of household expenditure: A reminder of the expenditure incurred by households on items such as food, electricity, education, and health. This is shown to the respondent before he/she answers the question on willingness to pay.

Box 3.3

The closed-ended question on willingness to pay in the household survey

After a preliminary discussion on piped water supply system as a possible long-term solution to the arsenic problem, the perceived advantages of piped supply, and the favored agency to implement and manage such schemes in the village, respondents were asked the following question in the interview to assess his/her willingness to pay for piped water (text reproduced):

"Let me now turn to the question of cost-sharing. But, before that, I should give you some details of a piped water supply scheme for the village. Water will be supplied twice a day — for two hours in the morning and two hours in the evening. The pressure will be adequate to fully satisfy your need for drinking, cooking, bathing, and washing. The timings of the water supply will be reliable. For those opting for public standposts, one post will be shared by five/seven families. Each household opting for a public standpost will have a standpost within 60 yards from the house. Potable quality water will be supplied, free from arsenic and bacteriological contamination.

The water supply scheme will be implemented and managed by the agency of your choice. You have a choice between a public standpost and a domestic connection. Please bear in mind that I am not talking about an actual scheme being planned for your village, but about a possible scheme that could be implemented in future.

PUBLIC STANDPOST

(a) In case you opt for a standpost, the capital cost you will have to contribute is ——— Taka [200/400/600/800/1000]* (The capital cost has to be paid once only). [Enumerator: please fill the allotted capital cost from the numbers given.]

(b) In addition to capital cost, you will have to contribute ——— Taka [10/20/30/40/50]* as O&M cost per month for the standpost option. [Enumerator: please fill the allotted O&M cost from the numbers given.]

DOMESTIC CONNECTION

(c) In case you opt for a domestic connection, the capital cost you will have to contribute is ——— Taka [500/750/1000/2000/3000]* (The capital cost has to be paid once only). [Enumerator: please fill the allotted capital cost from the numbers given.]

(d) In addition to capital cost, you will have to contribute ——— Taka [30/50/70/90/100]* as O&M cost per month for the domestic connection option. [Enumerator: please fill the allotted O&M cost from the numbers given.]

(e) Given the above cost associated with a standpost and a domestic connection, what would you choose?

[Before answering, consider the advantages of piped water supply. Also, at the same time, keep in mind the fact that your income is limited. In order to pay for piped water supply you will have to sacrifice some other consumption. Enumerator: use Card 11 to remind the respondent the expenditures they are incurring on various items, including food, clothing, electricity, children's education, and health]

Willing to pay capital and O&M charges for a public standpost	1
Willing to pay capital and O&M charges for a domestic connection	2
Not willing to pay the stated amount for either	3"

** One of the five sets of numbers to be used in different sub-samples (see Annex A).*

and the arsenic mitigation technology they found the most acceptable (out of the six selected for the study), with or without subsidy on the capital cost of the arsenic mitigation technology.

Socio-economic information on the household. Socio-economic status of the household was evaluated based on household income and assets, educational background, occupation, number and age of family members, type of house, with/without electricity connection.

3.2.2.2 Village survey

A village survey was designed to obtain information from key respondents at the village level, such as village elders and the village head. The village survey was fielded after the household survey to gather more general information on the socio-economic conditions in the village, water sources, use of tubewells, awareness about the arsenic problem, testing/ monitoring of tubewell water, the number of arsenic-contaminated tubewells, use of arsenic mitigation technologies, preference for piped water schemes, and willingness to pay for such schemes. Data from the village survey were used to cross-check the information obtained from the household survey.

3.2.3 Administering the survey

BRAC appointed five supervisors to field the survey. Four notes were prepared for the supervisors and enumerators with detailed instructions on how to conduct the surveys (see Annex A for details):

Note I: Instructions to supervisors and enumerators on the willingness to pay questionnaire

Note II: Instructions for selection of survey area

Note III: Key instructions to supervisors for carrying out the survey work

Note IV: Supervisor's daily tracking sheet

3.2.4 Data entry

Data entry was done by BRAC, with the help of trained data operators. This was done simultaneously with the field survey. As the survey for each district was completed, the completed and verified questionnaires were sent to the BRAC's Dhaka office for data entry.

3.2.5 Analysis of data

Data for the sample (arsenic-contaminated) area and control (arsenic-free) area as well as for the third area of study (arsenic-affected areas with a significant shift to public tubewells) were analyzed to understand the factors underlying the demand for arsenic-free, safe drinking water, rural households' preferred choice among the six selected arsenic mitigation technologies, whether they would opt for piped water supply, and whether they would prefer arsenic mitigation technologies to piped water schemes.
A multinomial logit model was used to estimate willingness to pay for piped water supply (standpost/ domestic connection) (discussed in Annex B).
The estimated model related respondents' willingness to pay for piped water to household income, other socio-economic characteristics of the respondent, and the type of service (standpost versus private connection). The model applied to the arsenic-affected area also included a composite explanatory variable representing the respondent's awareness and concern for the arsenic problem.

3.3 Key features of the contingent valuation survey fielded in Bangladesh

It has been mentioned in Section 3.1 that to obtain reliable results from a contingent valuation survey, the questionnaire should be appropriately designed to control potential biases. Validity checks should also be carried out. Both these issues were addressed in the contingent valuation survey fielded in Bangladesh, which are discussed in the following sections.

3.3.1 Survey method

Enumerators were specially trained by contingent valuation experts and BRAC to conduct in-person interviews. Care was taken that the household head (usually a male) was interviewed along with female members of the household because the household head typically takes most of the decisions in rural Bangladesh. If the household head was not present, a convenient time was fixed when the head would be present. Female members of the household were encouraged to answer questions on the sources and uses of water and convenience of accessing the source, as they would have more experience of these aspects.

3.3.2 Elicitation method

For value elicitation, either an open-ended elicitation method (which asks the respondent to state the sum he/she is willing to pay) or a closed-ended referendum type elicitation method (where the respondent is asked whether or not he/she would be willing to pay a particular amount for the good being valued) can be used. The advantage of a closed-ended question format is that it is convenient for the respondent to consider the suggested price options, especially since the good is not available in the market. A more compelling reason for using the closed-ended format is that strategic biases in the responses can be controlled more effectively (as noted earlier in Section 3.1).

The Bangladesh study uses the single referendum protocol coupled with split sampling, which is a widely accepted methodology for value elicitation. This format for value elicitation has been applied in a number of recent studies including the study by Pattanayak et al. (2002) on improved water supply in Kathmandu Valley.

A closed-ended referendum type questionnaire format was used in this study to elicit the willingness to pay for piped water supply options for both standposts and domestic connections (Box 3.3). This was followed by an open-ended question, which was intentionally designed to assess the respondent's maximum willingness to pay.

3.3.3 Payment method

A scenario was carefully designed for the method of payment to minimize biases in willingness to pay responses. Respondents were given details of the piped water supply scheme for the village before eliciting the extent of their contribution to an agency of their choice. Respondents were asked whether they would be willing to pay the O&M charges and contribute to the capital cost in cash. Those unable to pay a share of the capital cost in cash were given the option of contributing partly in cash and partly in labor days, or only in labor days (the contribution to O&M payment could only be made in cash).

3.3.4 Control of biases and validation of the contingent valuation method

Repeated pre-testing and focus group discussions helped to minimize biases associated with contingent valuation surveys. The methods adopted for controlling some of the major biases are highlighted below.

Hypothetical scenario mis-specification bias was minimized by constructing realistic and meaningful scenarios in keeping with the needs of the study. Specially designed cards were used to provide detailed information on the symptoms of arsenic exposure (or arsenicosis), health risks, and the cost of treatment, both in the short term as well as following prolonged exposure to arsenic-contaminated water (Box 3.2). The cards also provided detailed information on alternative technologies for arsenic mitigation being promoted in Bangladesh. The brand names of these technologies were not revealed so that it would not be presumed that the survey was promoting a particular technology. The piped water option was introduced only after asking the respondent to identify his/her most preferred choice of arsenic mitigation technology. Finally, the respondent was asked to choose between the preferred technology and the option of piped water.

Strategic bias is typically introduced when the respondent attempts to influence the price of the commodity being valued and the outcome of the study. A closed-ended referendum type elicitation format was used to control such a bias. The values used in the referendum were based on the actual O&M and capital cost of pilot piped water schemes in rural Bangladesh (see Annex C). A split sampling methodology was also used to analyze responses to variations in the referendum values (see Annex A).

Box 3.4

Evolution of contingent valuation methodology

Initially contingent valuation studies (conducted by Davis, 1963; Randall et al., 1974) focused on incentives and free-rider issues, with psychometric issues treated as incidental problems that would disappear when the subject had a positive incentive to be truthful. Davis employed an open-ended protocol in which the subject was asked to state his/her maximum willingness to pay. Randall employed a sequential bidding protocol in which the subject was asked for a series of votes on referendums (take-it or leave-it for a quoted price, done repeatedly for a series of prices) converging to a willingness to pay figure.

The most commonly used protocols in the early 1980s were the open-ended or used payment cards, the latter requesting a choice from a series of ranges. The referendum protocol, stripped of the sequential bidding feature so that the subject was offered a single bid that varied across subjects according to an experimental design, was re-introduced by Bishop and Heberlein (1979) and Hanemann (1984). The protocol was further developed in the later half of the 1980s. By 1993, the referendum protocol with a single bid, or in some applications with a follow-up bid known as double referendum, eclipsed the open-ended protocol. A blue-ribbon panel, assembled by the National Oceanic and Atmospheric Administration to assess the reliability of contingent valuation methodology, endorsed the single referendum protocol as the preferred procedure for contingent valuation study.

It is known that the single referendum protocol is statistically inefficient compared to the open-ended protocol, requiring a substantially larger sample to achieve the same level of precision. It also needs more complex econometric techniques to derive estimates of willingness to pay. Yet the referendum protocol has found widespread and relatively uncritical acceptance. This is because the analysts feel that this protocol is easier for the respondent to answer and is incentive compatible, and thus relatively free from strategic biases. Also, it is felt that the referendum method mimics the political referendums, which are an accepted mechanism for social choice.

Literature on contingent valuation over the last two decades has focused on methodological issues, particularly the issue of biases in responses obtained to the valuation question. A number of studies have tested for biases, such as the hypothetical scenario mis-specification bias and strategic bias, and the findings have been useful in understanding the magnitude and direction of the biases as well as the psychometric issues in contingent valuation. Based on the results of these studies, questionnaires can be designed better and biases minimized.

3.3.5 Validation of the contingent valuation method

The econometric model used for analyzing the responses of households to the valuation question in the survey helped to ascertain whether the responses were consistent with the economic theory, particularly whether the demand for piped water increased with household income and decreased with hikes in piped water charges. For further validation of the responses, the estimates of willingness to pay obtained by the contingent valuation method were compared with those obtained by the revealed preference method. The latter estimates were derived from the information collected in the survey on changes of source of drinking water due to arsenic contamination of the previous source and the cost this has imposed on the households, particularly the cost of time spent to collect water and the cost of boiling pond water to make it safe for drinking.

Socio-Economic Profile of the Respondents Covered in the Household Survey

4

To understand people's preferences and willingness to pay for safe water options, it is important to gather information on the socio-economic characteristics of the respondents covered in the survey. Indeed, the econometric models that have been applied in this study to explain the willingness to pay for piped water and the choice between piped water and other arsenic mitigation technologies have used the socio-economic characteristics of the respondents as explanatory variables (details are presented and discussed in Chapters 8-10). These data have also provided inputs into the analysis presented in subsequent chapters.

This chapter presents key socio-economic and demographic features of the respondents in the sample (arsenic-contaminated) and control (arsenic-free) areas based on responses to the household survey. The first section covers the age and gender of the respondents, their educational achievements, and occupation. As the majority of the respondents were themselves heading the households, and are believed to be instrumental in household decision-making, details of the household head are also presented. Characteristics of the respondents' families, including average family size, number of earning members, monthly income, ownership of assets, and residence patterns are discussed. Data have been analyzed to compare poor and non-poor groups using selected indicators. The dichotomy between poor and non-poor households is important to study, as there may be significant differences between the two groups with regard to their preferences for piped water and arsenic mitigation technologies. This grouping is also important when discussing the issue of affordability of the technologies.

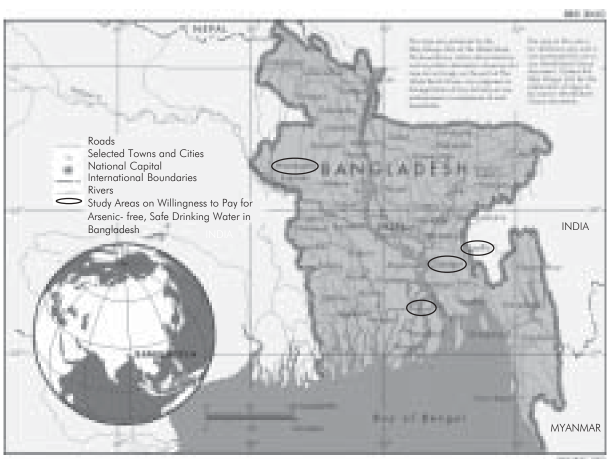
As mentioned earlier in Chapter 3, 2,880 households were surveyed in the study. Respondents were randomly selected from three areas — an area affected by large-scale arsenic contamination (the sample area), an arsenic-free area (the control area), and an arsenic-affected area where most people have shifted to public deep tubewells (Table 4.1 lists the districts surveyed and the number of respondents interviewed in each area; also see Map). The study focuses mainly on households in the sample and control areas. Data on the respondents' socio-economic characteristics are presented area-wise and district-wise for the sample and control areas in this chapter. The analyses presented in Chapters 5-9 also cover these areas. The behavior

Table 4.1: Distribution of respondents by district and sample type

District	Number of households/respondents
Sample area (arsenic-affected)	
Barisal	807
Chandpur	778
Chapai Nawabganj	845
Total	**2,430**
Control area (arsenic-free)	
Chapai Nawabganj (Bolarhat *thana*)	150
Commilla (Commilla Sadar *thana*)	150
Total	**300**
Area where there has been a large-scale shift to deep tubewells (arsenic-contaminated area)	
Barisal (Banaripara *thana*)	150
Total (all households surveyed)	2,880

Note: These figures are common to all the tables in this chapter unless specifically mentioned otherwise.

and preferences of households in the third area (those that have shifted to public tubewells) is also of interest. However, the distinct character of respondents in this area and their preferences calls for a separate analysis, which is presented in Chapter 10.



The areas covered in the survey

4.1 Key characteristics of the respondents

4.1.1 Gender

Most of the respondents interviewed were male (92 percent in the sample area and 96 percent in the control area) (see Table 4.2). There are a relatively smaller number of female respondents in the sample

Table 4.2: Distribution of respondents by gender

District	Male	Female	Total
Barisal	761	46	807
Chandpur	686	92	778
Chapai Nawabganj	778	67	845
Total sample area	**2,225 (91.6)**	**205 (8.4)**	**2,430**
Control area	**287 (95.7)**	**13 (4.3)**	**300**

Note: Figures in brackets are percentages.

as, in most cases, interviews were held with the household head usually a male (see Tables 4.6 and 4.7). District-wise, the proportion of female respondents was relatively higher in Chandpur compared to Chapai Nawabganj and Barisal.

4.1.2 Age

Most respondents in both areas surveyed were between 21-60 years (Table 4.3), the average age being about 42 years in the sample area and 41 years in the control area. Only a few respondents were above 60 years (10 percent in the sample area and about 11 percent in the control area) or below 20 years (5 percent and 2 percent, respectively).

4.1.3 Level of education

The level of education among the respondents was generally low. In the sample area, about one-third of

Table 4.3: Distribution of respondents by age

District	Age group					Average age (years)
	Up to 20 years	21-40 years	41-60 years	Above 60 years	Total	
Barisal	29	387	300	91	807	42.9
Chandpur	16	359	318	85	778	43.9
Chapai Nawabganj	70	441	263	71	845	39.9
Total sample area	**115 (4.7)**	**1,187 (48.8)**	**881 (36.2)**	**247 (10.2)**	**2,430**	**42.2**
Control area	**6 (2.0)**	**134 (44.7)**	**126 (42.0)**	**34 (11.3)**	**300**	**41.2**

Note: Figures in brackets are percentages.

Table 4.4: Level of education of the respondents

District	Illiterate	Up to Class V	Education up to Class X	SSC passed	BA and above	Total
Barisal	192	258	151	171	35	807
Chandpur	227	212	165	116	58	778
Chapai Nawabganj	439	143	122	114	27	845
Total sample area	**858 (35.3)**	**613 (25.2)**	**438 (18.0)**	**401 (16.5)**	**120 (4.9)**	**2,430**
Control area	**123 (41.0)**	**77 (25.7)**	**53 (17.7)**	**38 (12.7)**	**9 (3.0)**	**300**

Note: Figures in brackets are percentages.

the respondents were illiterate and a quarter had been educated only up to Class V (Table 4.4). The situation was similar in the control area: about 41 percent were illiterate and about 25 percent had been educated up to Class V. District-wise figures indicate that the proportion of illiterate respondents was relatively higher in Chapai Nawabganj compared to the other two districts. In the sample area, approximately 17 percent had completed their school education (passed the SSC examination), and 5 percent had graduated or had acquired a higher educational qualification. In the control area, the corresponding proportions were about 13 percent and 3 percent, respectively.

4.1.4 Occupation

As the survey covered only rural households, a significant number of respondents were engaged in agriculture-related activities. A sizeable number were farmers (39 percent in the sample area and 40 percent in the control area) or agricultural laborers (about 5 percent in the sample area and 12 percent in the control area) (Table 4.5). Business and service were next in importance after farming, with 19 percent and 9 percent of the respondents in the sample area, and 19 percent and 8 percent in the control area, engaged in business and service, respectively. A significant number of respondents in both areas (28 percent in the sample area and 21 percent in the control area) were engaged in other occupations (self-employed or housewives), or had retired or were unemployed.

District-wise figures indicate that the proportion of farmers and agricultural laborers was higher in Chapai Nawabganj compared to Barisal and Chandpur, while the proportion of respondents engaged in service was relatively higher in Barisal and Chandpur than in Chapai Nawabganj.

4.1.5 Relationship with the household head

Most respondents (97 percent in the control area and 81 percent in the sample area) were heading the household themselves (see Table 4.6). Others were

Table 4.5: Main occupation of the respondents

District	Occupation					
	Farmer	Agr. laborer	Service	Business	Others	Total
Barisal	317	33	107	121	229	807
Chandpur	251	34	89	161	243	778
Chapai Nawabganj	384	54	34	171	202	845
Total sample area	**952 (39.2)**	**121 (5.0)**	**230 (9.5)**	**453 (18.6)**	**674 (27.7)**	**2,430**
Control area	**121 (40.3)**	**37 (12.3)**	**24 (8.0)**	**56 (18.7)**	**62 (20.7)**	**300**

Note: Figures in brackets are percentages.

Table 4.6: Respondent's relationship with the household head

District	Relationship with household head				
	Self	Wife	Son	Others	Total
Barisal	624	13	138	32	807
Chandpur	661	30	69	18	778
Chapai Nawabganj	684	33	101	27	845
Total sample area	**1,969 (81.0)**	**76 (3.1)**	**308 (12.7)**	**77 (3.2)**	**2,430**
Control area	**290 (96.7)**	**3 (1.0)**	**6 (2.0)**	**1 (0.3)**	**300**

Note: Figures in brackets are percentages.

either the household head's son (13 percent in the sample area and 2 percent in the control area) or the wife of the household head (3 percent and 1 percent, respectively). Only a few respondents in the sample area (3 percent) had other links with the household head.

4.1.6 Gender of the household head

Almost all the household heads in the sample and control areas were male (94 percent and 96 percent, respectively) (Table 4.7). District-wise figures show that the proportion of female-headed households was higher in Chandpur compared to the other two districts.

4.1.7 Occupation of the household head

Farming was the main occupation of the household head in most areas, followed by business and service (see Table 4.8). In the sample area, about 45 percent of the household heads were farmers or agricultural laborers. In the control area, the corresponding proportion was about 60 percent. The proportion of household heads in business was about 21 percent in the sample area and 17 percent in the control area

Table 4.7: Gender of the household head

District	Gender of the household head	
	Male	Female
Barisal	763	44
Chandpur	716	62
Chapai Nawabganj	811	34
Total sample area	**2,290 (94.2)**	**140 (5.8)**
Control area	**288 (96.0)**	**12 (4.0)**

Note: Figures in brackets are percentages.

while the proportion of households engaged in service was about 17 percent and 12 percent, respectively.

4.2 Household profile

This section briefly discusses the socio-economic characteristics of the respondents' families.

4.2.1 Age composition

There was considerable similarity in the sample and control areas as well as across the three districts in terms of the age composition of the families (Table 4.9). Roughly half the members of the households surveyed

Table 4.8: Occupation of the household head

District	Main occupation of the household head						
	Total households	Farmer	Agr. laborer	Service	Business	Self-employed	Others
Sample area							
Barisal	807	349	47	165	124	25	97
Chandpur	778	196	34	174	179	50	145
Chapai Nawabganj	845	391	66	83	204	34	67
Total sample area	**2,430**	**936 (38.5)**	**147 (6.0)**	**422 (17.4)**	**507 (20.9)**	**109 (4.5)**	**309 (12.7)**
Control area							
Chapai Nawabganj	150	76	39	4	23	7	1
Commilla	150	50	15	32	28	11	14
Total control area	**300**	**126 (42.0)**	**54 (18.0)**	**36 (12.0)**	**51 (17.0)**	**18 (6.0)**	**15 (5.0)**

Note: Figures in brackets are percentages.

Table 4.9: Age profile of the family members (% distribution)

District	Below 6 years	6-15 years	16-55 years	Above 55 years	Total
Barisal	13	26	53	8	100
Chandpur	14	26	52	7	100
Chapai Nawabganj	14	26	54	6	100
Total sample area	**14**	**26**	**53**	**7**	**100**
Control area	**14**	**26**	**55**	**5**	**100**

Table 4.10: Average family size

District	Average family size		
	No. of males	No. of females	Total
Barisal	3.2	2.9	6.2
Chandpur	3.3	3.0	6.3
Chapai Nawabganj	3.1	2.9	6.0
Total sample area	**3.2**	**2.9**	**6.1**
Control area	**3.0**	**2.9**	**6.0**

were between 16-55 years, one-fourth were between 6-15 years, and 14 percent were less than 6 years. Of the households covered, only 7 percent in the sample area and 5 percent in the control area were above 55 years.

4.2.2 Family size and number of earning members

The average family size was 6.1 in the sample area and 6.0 in the control area (Table 4.10). Most households (64 percent in the sample area and 55 percent in the control area) had only one earning member (Table 4.11). About 24 per cent of the households in the sample area and about 31 percent in the control area had two earning members. In both areas, only a small proportion of households (12 percent in the sample area and 14 per cent in the control area) had three or more earning members. On an average, each household had 1.5 earning members in the sample area and 1.6 in the control area (Table 4.12). District-wise, in the sample area, the number of earning members per household in Chandpur was slightly higher than that in Chapai Nawabganj and Barisal. In the control area, the number of earning members per household was higher in Commilla than in Chapai Nawabganj.

4.2.3 Monthly income

Two indicators — monthly income and ownership of assets — were used to establish the standard of living

Table 4.11: Earning members in each household (% distribution)

District	Earning members				
	One	Two	Three	More than three	All
Barisal	65	25	7	3	100
Chandpur	59	27	10	4	100
Chapai Nawabganj	67	21	9	3	100
Sample area	**64**	**24**	**9**	**3**	**100**
Control area	**55**	**31**	**11**	**3**	**100**
Total	**63**	**25**	**9**	**3**	**100**

Table 4.12: Average number of earning members per household

District	Average number of earning members
Sample area	
Barisal	1.47
Chandpur	1.62
Chapai Nawabganj	1.51
Total sample area	**1.53**
Control area	
Chapai Nawabganj	1.54
Commilla	1.69
Total control area	**1.62**

Table 4.13: Average household income

District	Mean	Standard deviation	Median
Sample area			
Barisal	4,441.64	4,872.87	3,000.00
Chandpur	5,634.38	6,752.97	4,000.00
Chapai Nawabganj	3,764.73	3,451.37	3,000.00
Total sample area	**4,588.13**	**5,215.30**	**3,000.00**
Control area			
Chapai Nawabganj	2,753.00	1,420.44	2,200.00
Commilla	6,422.00	6,100.80	5,000.00
Total control area	**4,587.50**	**4,788.50**	**3,000.00**

Note: Figures are in Tk per month.

of the household. The findings indicate that the average income per household was Tk 4,588 per month in the sample and control areas (Table 4.13).[16] In the sample area, the average income level was highest in Chandpur, followed by Barisal and Chapai Nawabganj, which is in accordance with the findings of the survey that the number of earning members per household in Chandpur was a little higher than in Chapai Nawabganj and Barisal (Table 4.12).

In the control area, the average income in Commilla was more than twice the average income in Chapai Nawabganj. The reasons for this difference may be that the area surveyed in Commilla was more developed than the area surveyed in Chapai Nawabganj and the number of earning members per household was higher in Commilla than in Chapai Nawabganj (see Table 4.12). Moreover, in Commilla, a larger number of household heads were engaged in relatively more remunerative occupations — 40 percent of the household heads were engaged in service or business, and 43 percent in farming, whereas in Chapai Nawabganj, 18 percent were engaged in service or business, and 80 percent in farming (Table 4.8).

In terms of income distribution, there was considerable similarity between the sample and control areas (the distribution of households according to aggregate monthly income of all earning members is presented in Table 4.14). In the sample area, households with a monthly income in the range of Tk 1,001-5,000 accounted for about 75 percent of the total households. Within this group, approximately half the households earned Tk 1,001-2,000 a month (22 percent) and Tk 2,001-3,000 per month (28 percent). Households earning up to Tk 1,000 a month constituted only about 3 percent of the total households while the remaining 22 percent were earning over Tk 5,000 per month. In the control area, too, 74 percent of the households were earning Tk 1,001-5,000 per month. Those earning Tk 1,001-3,000 a month constituted about 49 percent of the total households.

An inter-district comparison of household income indicates that the proportion of households in the high-income category (household income over Tk 10,000 per month) was highest in Chandpur district (about 7 percent), followed by Barisal (4 percent) and Chapai Nawabganj (3 percent). A significant number of households in Commilla district (about 13 percent) were also in the high-income category.

4.2.4 Ownership of assets

Data were collected on ownership of household assets based on a list of 11 items (see Table 4.15). The pattern of asset ownership in both areas surveyed was

Table 4.14: Distribution of households according to monthly income

District	Average monthly income of households (Tk)								Total
	<500	501-1,000	1,001-2,000	2,001-3,000	3,001-5,000	5,001-7,000	7,001-10,000	>10,000	
Sample area									
Barisal	4	14	147	246	243	67	53	33 (4.1)	807
Chandpur	2	9	135	174	219	93	90	56 (7.2)	778
Chapai Nawabganj	5	44	254	255	152	51	61	23 (2.7)	845
Total sample area	**11 (0.5)**	**67 (2.8)**	**536 (22.1)**	**675 (27.8)**	**614 (25.3)**	**211 (8.7)**	**204 (8.4)**	**112 (4.6)**	**2,430**
Control area									
Chapai Nawabganj	0	6	65	42	28	7	2	0 (0.0)	150
Commilla	1	2	7	32	49	25	15	19 (12.6)	150
Total control area	**1 (0.3)**	**8 (2.7)**	**72 (24.0)**	**74 (24.7)**	**77 (25.7)**	**32 (10.7)**	**17 (5.7)**	**19 (6.3)**	**300**

Note: Figures in brackets are percentages.

[16] One Taka is approximately US$ 0.017 (August 2002).

Table 4.15: Assets owned by households (%)

Asset	Percentage of households owning the assets	
	Sample area	Control area
Bicycle	33.0	28.7
Electric fan	25.1	31.7
Kerosene stove	4.9	0.3
LPG gas stove	0.4	0.0
Pressure cooker	2.1	0.3
Sewing machine	6.6	7.0
Telephone	0.5	0.3
Television	14.3	15.3
Transistor radio	47.5	45.7
Two-wheeler/car	1.5	0.7
Watch and clock	73.5	72.7

similar. The most commonly owned asset was a watch/clock (approximately 73 percent of households in both the sample and control areas), followed by a transistor radio (about 47 percent). Other commonly owned assets in both areas were bicycles and electric fans. Amongst other assets, ownership of televisions and sewing machines was relatively more common.

4.2.5 Pattern of residence: Single or multiple families

The pattern of residence varied across the surveyed districts. In the sample area, multiple families resided in 62 percent of the houses compared to 54 percent in the control area.[17] There were differences across districts as well. While the majority of households in Chapai Nawabganj reported only a single family residing in the house, most respondents in Barisal and Chandpur reported that multiple families were residing in the same house (Table 4.16).

4.2.6 Other key characteristics

Most families were residing in their own homes (Table 4.17) rather than in rented accommodation. There were considerable variations across the areas with regard to whether houses had an electricity connection. About one-third of the houses in the sample area had electricity connections (Table 4.17), ranging across the districts from about 28 percent in Chapai Nawabganj to 36 percent in Barisal. In the control area, approximately half the houses had electricity connections. District-wise differences were significant. In Commilla 83 percent

Table 4.16: Pattern of residence

District	No. of houses	No. of families residing in the house	
		Single	Multiple
Barisal	807	180	627
Chandpur	778	153	625
Chapai Nawabganj	845	593	252
Total sample area	**2,430**	**926 (38.1)**	**1,504 (61.9)**
Control area	**300**	**137 (45.7)**	**163 (54.3)**

Note: Figures in brackets are percentages.

[17] Whether there was a single family or multiple families staying in the house was decided on the basis of the number of kitchens in the house.

had electricity connections compared to 17 percent in Chapai Nawabganj. This could be because the households surveyed in Commilla are in Sadar *thana*, a more developed area of the district.

In the sample area, average expenditure on electricity varied between Tk 44-51 per month per family (Table 4.17). In the control areas families spent approximately Tk 22 in Chapai Nawabganj, and as much as Tk 110 a month in Commilla (possibly because of the large number of houses with electricity connections in this area).[18]

The average number of rooms per household was 3.25 in the sample area and 2.66 in the control area (Table 4.17). In the sample area, the average number of rooms per household was higher in Barisal and Chandpur compared to Chapai Nawabganj.

In the sample area, about 40 percent of the households had one or two rooms in the house. The corresponding figure for the control area was higher (61 percent) (Table 4.18). The proportion of households with three to five rooms was about 50 percent in the sample area and about 32 percent in the control area, while the proportion of households with six or more rooms was 10 percent in the sample area and 6 percent in the control area.

4.3 Profile of poor households

As mentioned earlier, there could be significant differences in the preferences and willingness to pay for piped water and arsenic mitigation technologies between poor and non-poor households. Moreover, affordability may be an important issue for poor households. Accordingly, data for poor and non-poor households have been examined separately when analyzing household preferences for piped water and arsenic mitigation technologies for the sample and control areas in Chapters 7 and 8. This section presents a profile of poor households in terms of key socio-economic characteristics and a comparison with non-poor households. Since the focus is on the differences between the poor and non-poor, household data for the sample and control areas were combined when tabulating the averages.

For the purpose of this study, households in rural areas earning less than Tk 3,600 per month were defined as 'poor'.[19] This definition is based on the

Table 4.17: Ownership of house and electricity connection

District	Ownership of house (No. of households)		Electricity connection (No. of households)		Average expenditure on electricity*	Average number of rooms
	Own	Not own	Yes	No		
Sample area						
Barisal	798	9	294	513	44.1	3.58
Chandpur	759	19	235	543	51.0	3.47
Chapai Nawabganj	807	38	234	611	48.2	2.72
Total sample area	**2,364 (97.3)**	**66 (2.7)**	**763 (31.4)**	**1,667 (68.6)**	**47.8**	**3.25**
Control area						
Chapai Nawabganj	143	7	26	124	21.8	2.68
Commilla	146	4	125	25	109.5	2.63
Total control area	**289 (96.3)**	**11 (3.7)**	**151 (50.3)**	**149 (49.7)**	**65.7**	**2.66**

Note: Figures in brackets are percentages.
** Tk per month per household.*

[18] The average expenditure on electricity in Table 4.17 is a simple average of the expenditure reported by the households covered in the survey.
[19] This definition of poverty is based on the following sources: Poverty Monitoring Survey, May 1999, CIRDAP; and Report on CIRDAP-BBS National Seminar on Poverty Monitoring 1997, CIRDAP (Centre on Integrated Rural Development for Asia and the Pacific, Dhaka), 1998.

Table 4.18: Distribution of households according to number of rooms in the house

District	Number of rooms						
	One	Two	Three	Four	Five	Six +	Total households
Barisal	32	154	319	156	43	103	807
Chandpur	50	234	176	187	37	94	778
Chapai Nawabganj	169	335	111	139	37	54	845
Total sample area	**251 (10.3)**	**723 (29.8)**	**606 (25.0)**	**482 (19.8)**	**117 (4.9)**	**251 (10.3)**	**2,430**
Control area	**33 (11.0)**	**151 (50.3)**	**58 (19.3)**	**31 (10.3)**	**8 (2.7)**	**19 (6.3)**	**300**

Note: Figures in brackets are percentages.

Table 4.19: Number of poor and non-poor households

District	Poor	Non-poor	Total
Sample area			
Barisal	453 (56.1)	354 (43.9)	807
Chandpur	355 (45.6)	423 (54.4)	778
Chapai Nawabganj	571 (67.6)	274 (32.4)	845
Total sample area	**1,379 (56.7)**	**1,051 (43.3)**	**2,430**
Control area			
Chapai Nawabganj	119 (79.3)	31 (20.7)	150
Commilla	51 (34.0)	99 (66.0)	150
Total control area	**170 (56.6)**	**130 (43.4)**	**300**
Total	1,549 (56.7)	1,181 (43.3)	2,730

basic needs approach. By this definition about 57 percent of households covered in the survey in both the sample and control areas can be considered poor (Table 4.19).

District-wise, the proportion of poor households in the sample area was highest in Chapai Nawabganj (about 68 percent), followed by Barisal (56 percent). The proportion of poor families in Chandpur was comparatively low (46 percent), which is to be expected given that average household income in this district was relatively high (see Tables 4.13 and 4.14). In the control areas of Commilla and Chapai Nawabganj, the proportion of poor households was 34 percent and 79 percent, respectively. The low proportion of poor households in Commilla reflects the high average income level in this area (see Tables 4.13 and 4.14).

4.3.1 Poor and non-poor households: A comparison

Significant differences emerge when the main indicators for poor and non-poor families are compared. As can be seen from Table 4.20, the level of educational attainment was relatively lower among poor households. In approximately half these households, the head was illiterate compared to 23 percent among non-poor households. Only 4 percent of the heads in poor households (compared to 17 percent in non-poor households) had completed their school education or attained a higher degree.

Expectedly, income levels differed considerably. The monthly average income of poor households was Tk 2,332, while that for non-poor households was Tk 7,547. There were also significant differences in terms of the main source of household income.

Working as agricultural laborers on farms was the main source of income for 12 percent of the poor households, compared to just 1 percent of non-poor households. In 28 percent of non-poor households the main source of income was service; the corresponding figure for poor households was 8 percent. Similarly, the proportion of households in which business was the main source of income was higher among non-poor households (24 percent) than that among poor households (17 percent). Poor households owned on an average fewer assets (1.47) compared to non-poor households (2.9) based on the same list of 11 assets used in the sample and control areas (see Table 4.15 for a detailed listing of assets).

Given their relatively lower incomes, poor households often found it difficult to balance their household budget. About 8 percent reported a regular deficit of income over expenditure, and 30 percent occasionally had a deficit. In contrast, only 9 percent of non-poor households reported that they had a regular or occasional deficit, 37 percent could balance income and expenditure, and 54 percent had a surplus of income over expenditure.

Poor households, on an average, spent less on electricity (Tk 22 a month) as compared to non-poor households (Tk 86 a month). Only about 20 percent of poor families had an electricity connection in the house, compared to 51 percent of non-poor households.

Table 4.20: Comparison of poor and non-poor households

Indicator	Poor	Non-poor
1. Educational qualification of the household head (% HH)		
Illiterate	52	23
School education up to Class V	26	26
School education beyond Class V but had not completed SSC	18	34
Completed SSC and higher level of education	4	17
2. Average monthly income (Tk)	2,332	7,547
3. Main source of household income (% HH)		
Farming	47	28
Agricultural labor	12	1
Service	8	28
Business	17	24
Others	16	19
4. Number of assets owned*	1.47	2.90
5. Household income and expenditure (% HH)		
Regular deficit	8	1
Occasional deficit	30	8
Balanced budget	46	37
Surplus of income over expenditure	16	54
6. Households with electricity (%)	20	51
7. Monthly expenditure on electricity (Tk)	22	86
8. Average number of rooms in the house	2.6	3.9
9. Children between 6-15 years attending school (%)	78	85

Note: Data for the sample and control areas have been combined. N = 2,730.
** Based on a list of 11 assets (see Table 4.15).*

Table 4.21: Type of house and material used by poor and non-poor households: A comparison (%)

Indicator	Poor	Non-poor
Floor		
Cement/brick	4	15
Soil	96	85
Walls		
Tin	36	58
Cement/brick	12	20
Soil	20	13
Bamboo & others	32	9
Roof		
Tin	85	87
Concrete	2	8
Tiles	10	4
Straw & others	3	1

Note: Data for the sample and control areas have been combined.

In terms of the building materials used, there were no significant differences between the types of houses the poor and non-poor households resided in (see Table 4.21 for details).

4.4 Summing up

A significant number of respondents (more than 90 percent) were male and between 21-60 years (about 85 percent). Most respondents were either illiterate or educated up to Class V. A little less than half were engaged in farming and about a quarter were in business or service. More than 80 percent of the respondents were heading the household themselves.

A typical household had six members, of whom only one was earning. About 75 percent of the households earned a monthly income of Tk 1,001-5,000 per month, although a significant number earned more than Tk 10,000 per month. The average household income was about Tk 4,600 per month. About 57 percent of the households were earning a monthly income of less than Tk 3,600 per month and could be considered 'poor'.

Non-poor households earned more than three times the amount that poor households earned. On an average, non-poor households earned Tk 7,500 per month compared to Tk 2,300 per month among poor households. About 80 percent of the respondents from poor households and about 50 percent from non-poor households were illiterate or had been educated up to Class V. More poor households were engaged in agricultural activities (60 percent) compared to non-poor households (30 percent). Only 20 per cent of poor households had an electricity connection in the house compared to about 50 percent of non-poor households with an electricity connection. Poor households spent on an average Tk 22 per month on electricity; non-poor households spent on average about Tk 86 per month on electricity.

Household Awareness of the Arsenic Problem and Related Concerns

5

To what extent are households in Bangladesh aware of the consequences of consuming arsenic-contaminated water? Do they perceive arsenic exposure as a potential threat to their families? Are they aware of the symptoms caused by arsenic toxicity? To assess people's awareness of the symptoms of arsenicosis, and their knowledge and concerns regarding the health risks associated with arsenic contamination, the study sought responses on whether households had heard about the problem of arsenic contamination in the country, their sources of information, whether they knew of any person affected by arsenicosis, if they were familiar with the symptoms of arsenicosis, and whether they could afford the cost of medical treatment. The findings of the survey are summarized in this chapter.

5.1 Awareness of the arsenic problem

Respondents in both the arsenic-affected and arsenic-free areas were asked whether they were aware of the arsenic problem and about the sources of their information. The results indicate widespread awareness, with approximately 87 percent of the respondents in the sample area and about 53 percent in the control area reporting that they were aware of the arsenic problem (Table 5.1). There were marginal differences across districts in the sample area. Awareness levels were highest in Chandpur (97 percent), followed by Chapai Nawabganj (85 percent), and Barisal (80 percent) (Figure 5.1). In the arsenic-free control area of Chapai Nawabganj, however, awareness was found to be low, with only 25 percent of the respondents reported that they were aware of the problem. The lack of awareness in this area may be due to the low level of education (53 percent of the respondents are illiterate compared to 35 percent in the sample area) coupled with the fact that arsenic contamination is not posing any immediate problem to residents of the area.

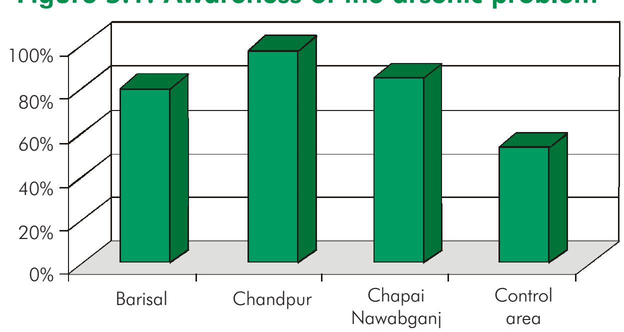
Respondents reported varied sources of information of the arsenic problem (Table 5.2). Radio and television were important sources followed by members of the family and other residents of the village. A sizeable number, particularly in Chandpur district, said they had heard about arsenic contamination through awareness programs

Table 5.1: Awareness of the arsenic problem

District	Is the respondent aware of the arsenic problem		Total
	Aware	Not aware	
Sample area			
Barisal	646 (80.0)	161 (20.0)	807
Chandpur	756 (97.2)	22 (2.8)	778
Chapai Nawabganj	715 (84.6)	130 (15.4)	845
Total sample area	**2,117 (87.1)**	**313 (12.9)**	**2,430**
Control area			
Chapai Nawabganj	37 (24.7)	113 (75.3)	150
Commilla	121 (80.7)	29 (19.3)	150
Total control area	**158 (52.7)**	**142 (47.3)**	**300**

Note: Figures in brackets are percentages.

Figure 5.1: Awareness of the arsenic problem



organized by NGOs and the government, and other organizations working in the field. As about a third of the respondents were illiterate and one-fourth had only an elementary school education (see Table 4.5), as expected only a few respondents had learnt about the problem from the newspaper.

5.2 Knowledge of arsenicosis cases

Details were sought on whether respondents knew anybody who had been affected by arsenicosis, and

Table 5.2: Source of information regarding the arsenic problem

Source	Barisal	Chandpur	Chapai Nawabganj	Total Sample area	Control area
Newspaper	77	101	84	262	19
Television	354	391	294	1,039	134
A family member	34	110	118	262	3
Residents of the village	226	369	384	979	44
Government/NGO/other agency	299	669	379	1,347	16
Radio	324	343	346	1,013	36
Others	2	5	55	62	18
Total number of respondents	**807**	**778**	**845**	**2,430**	**300**

Note: Multiple responses (selecting more than one source) were considered.

whether it was a relative, a neighbor, from the same village or from another village. As expected, none of the respondents in the control area (which is arsenic–free) had any knowledge about anyone affected by arsenicosis in the family or in the neighborhood. In the sample area, 44 of the 2,430 respondents (1.8 percent) stated that a family member had been affected by arsenicosis and 72 (3 percent) reported that they knew of persons with arsenicosis in the neighborhood (Table 5.3). Only a few respondents had heard of cases of arsenicosis in the village or a neighboring village (3.2 percent and 3.5 percent, respectively).

Reported cases of arsenicosis in the family or neighborhood were highest in Chandpur (about 10 percent), followed by Barisal and Chapai Nawabganj (Table 5.3), suggesting a comparatively higher incidence of arsenicosis in Chandpur.

One may notice an apparently contradictory trend in the findings. The figures indicate that while some households reported cases of arsenicosis in the family or in the neighborhood, most other households in the same village were not aware of these cases.

To confirm this trend, the responses of 540 households in 10 selected villages (53-55 households covered in each village) with a relatively higher incidence of arsenicosis were analyzed (Table 5.4). Data for these selected villages show that 38 households reported that they knew of a family member affected by arsenicosis, and 62 households reported that they knew of a person in the neighborhood affected by arsenicosis. However, of the remaining 440 households in the 10 selected villages, only 65 (15 percent) said that they knew of a person affected by arsenicosis in the village.

There could be two reasons for these conflicting findings. In some cases, the fact that family members were affected, or were suspected to be affected, by arsenicosis was being kept a secret and only the family and a few neighbors knew about it. Therefore, most of the people in the village were unaware of such cases in the village. Another possible explanation is that most respondents were reluctant to give information to an outsider (in this case the interviewer) about persons affected by arsenicosis in the village, especially if the disease had not been medically confirmed.

5.3 Awareness of the symptoms of arsenicosis

In order to assess household perceptions of the adverse health effects of consuming arsenic-contaminated water,

Table 5.3: Knowledge of arsenicosis cases in the sample area

	Barisal		Chandpur	
	Yes	No	Yes	No
Relative	11	796	27	751
Neighbor	18	789	48	730
In the village	18	789	54	724
In a neighboring village	16	791	56	722
	Chapai Nawabganj		**Total (three districts) (%)**	
	Yes	**No**	**Yes**	**No**
Relative	6	839	44 (1.8)	2,386 (98.2)
Neighbor	6	839	72 (3.0)	2,358 (97.0)
In the village	5	840	77 (3.2)	2,353 (96.8)
In a neighboring village	12	833	84 (3.5)	2,346 (96.5)

Table 5.4: Knowledge of arsenicosis cases in 10 selected villages with a relatively high incidence of arsenicosis

	No. of households
A. Total households	540
B. Households reporting a patient in the family	38
C. Households reporting a patient in the neighbor's house	62
D. Remaining households (A-B-C)	440
E. Of D, those reporting an arsenic patient in the village	65 (15% of D)

Table 5.5: Knowledge of the symptoms of arsenicosis and the effects of prolonged arsenic exposure

	Barisal	Chandpur	Chapai Nawabganj	Total Sample area	Control area
A. Is the respondent aware of the symptoms of arsenicosis					
Yes	206	170	264	640 (26.3)	47 (15.7)
No	253	289	152	694 (28.6)	104 (34.7)
Has some idea	348	319	429	1,096 (45.1)	149 (49.6)
B. Is the respondent aware that it takes a number of years for arsenic poisoning to manifest itself					
Yes	336	292	241	869 (35.8)	32 (10.7)
No	471	486	604	1,561 (64.2)	268 (89.3)
C. Is the respondent aware that the prolonged use of arsenic-contaminated water could lead to gangrene, cancer, or even death					
Yes	238	333	288	859 (35.3)	13 (4.3)
No	427	390	551	1,368 (56.3)	234 (78.0)
Respondents aware that arsenic-contaminated water can cause health problems but do not know that it causes cancer	126	55	6	187 (7.7)	53 (17.7)
Respondents not convinced that arsenic can cause cancer	16	0	0	16 (0.7)	0 (0.0)

Note: Figures in brackets are percentages.

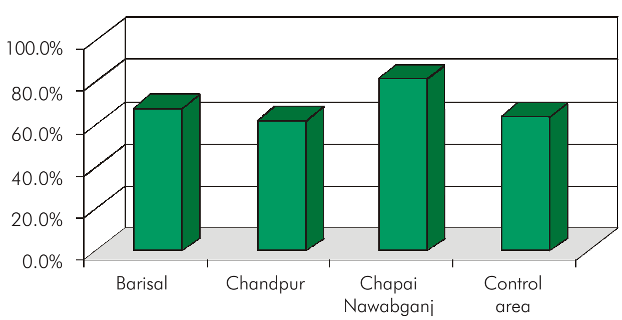
respondents were asked whether they were aware of the symptoms of arsenicosis. They were also asked whether they knew that arsenic poisoning takes a number of years to manifest itself, that a person may continue to use arsenic-contaminated water for years without being aware of the effects of arsenic poisoning, and that the prolonged use of arsenic-contaminated water could lead to gangrene, cancer, or in extreme cases death (Table 5.5). As part of the methodology, briefing cards were used to explain to the respondents the symptoms of arsenicosis, the three stages of arsenicosis, and the cost of medical treatment in the early and advanced stages (for details on the briefing cards, see Chapter 3).

Awareness of the symptoms of arsenicosis was slightly higher in the arsenic-affected sample area compared to the control area. While 26 percent of the respondents in the sample area reported that they were familiar with the symptoms and 45 percent said they had some idea of the symptoms, the corresponding figures for the control area were 16 percent and 50 percent, respectively (Table 5.5).

Household awareness of the symptoms of arsenic toxicity was independently assessed and recorded by the interviewers. Respondents who said they were familiar with all or some of the symptoms of arsenicosis were asked to describe the symptoms. These were then discussed with the interviewer using prepared cards. Based on the respondent's description of the symptoms and the subsequent discussion, the respondent's knowledge of the symptoms was evaluated. According to the interviewers, 53 percent of the respondents in the sample area and 49 percent in the control area knew the symptoms of arsenicosis or at least had some knowledge about them (Table 5.6).

The level of awareness varied across districts in the sample area. More respondents in Chapai Nawabganj reported knowing the symptoms of arsenicosis than in the other two districts (Table 5.5, Figure 5.2). However, according to the assessment of the interviewers, more households in Chandpur and Barisal were familiar with the symptoms of arsenicosis than in Chapai Nawabganj (Table 5.6, Figure 5.3).

Figure 5.2: Self-reported awareness of the symptoms of arsenicosis



Though many respondents were aware that the consumption of arsenic-contaminated water could adversely affect health, a number of respondents were not aware of the serious long-term health effects of consuming arsenic-contaminated water. Only about 36 percent of the respondents in the sample area and 11 percent in the control area (Table 5.5) knew that it takes a number of years for arsenic poisoning to manifest itself and that the prolonged use of arsenic-contaminated water can lead to arsenic-related diseases. The fact that in the advanced stages, arsenicosis may lead to gangrene or cancer, or even death, was known to only about 35 percent of the respondents in the sample area and about 4 percent in the control area (Table 5.5).

A comparison across districts suggests that households in Chandpur were more aware of the symptoms of arsenicosis, the adverse health impact of arsenic contamination, and the arsenic problem in general than in Chapai Nawabganj and Barisal (see Tables 5.1, 5.3, 5.5, and 5.6). This could be because the incidence of arsenicosis is higher in Chandpur (see Table 5.3) and there are more arsenic-contaminated tubewells in the area (see Chapter 6, Table 6.17) than in the other two districts. A number of programs on arsenic, supported by the government and NGOs, are currently being carried out in Chandpur, which may also have resulted in higher levels of awareness in this district.

Figure 5.3: Respondents' awareness of the symptoms of arsenicosis as assessed by the interviewer

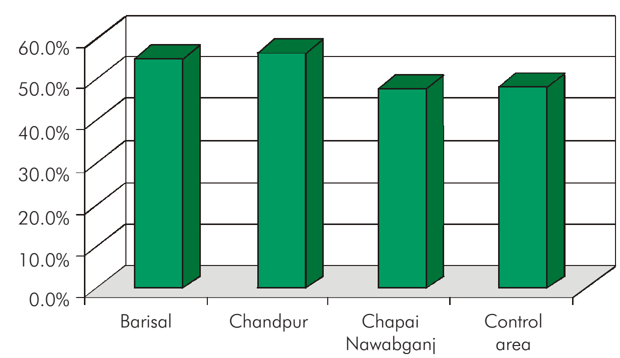


Table 5.6: Interviewer's assessment of respondents' awareness of the symptoms of arsenicosis

District	Interviewer's assessment		
	Respondent knows the symptoms well	Respondent has some idea	Total respondents
Sample area			
Barisal	89 (11.0)	363 (45.0)	807
Chandpur	130 (16.7)	319 (41.0)	778
Chapai Nawabganj	123 (14.6)	274 (32.4)	845
Total sample area	**342 (14.1)**	**956 (39.3)**	**2,430**
Control area	**14 (4.7)**	**132 (44.0)**	**300**

Note: Figures in brackets are percentages.

5.4 Affordability of medical treatment for arsenicosis

The capacity of households to meet the cost of treatment of arsenicosis is a significant issue that could impact household preferences for safe water options. During the interview, respondents were briefed about the cost of treatment of arsenicosis at different stages (which is minimal in the early stages but becomes high as the disease reaches an advanced stage).[20] Respondents were also informed that there is no cure for arsenicosis, and once the disease reaches an advanced stage it cannot be reversed (although medicine and/or surgery can prolong a patient's life and make his condition less painful). The only solution to arsenicosis is to shift to a safe water source. Respondents were then asked whether they could afford the cost of treatment if a family member got arsenicosis and it progressed to an advanced stage. Since none of the respondents in the control area knew of any case of arsenicosis, responses were obtained only for the sample area (Table 5.7).

Only a few respondents felt that they could afford the cost of treatment (3.3 percent). While about 30 percent said it would be difficult to meet the entire cost of treatment, more than half (67 percent) said that they could not afford even a part of the cost of treatment.

Responses to the issue of affordability of medical treatment appeared to be linked to the level of household income. Respondents who felt they could

Table 5.7: Affordability of the cost of arsenicosis treatment: Sample area

Can the household afford the cost of treatment if a family member is affected by arsenicosis and it progresses to an advanced stage?				
District	Yes	It will be difficult	Cannot afford it at all	Total
Barisal	31	269	507	807
Chandpur	21	276	481	778
Chapai Nawabganj	27	177	641	845
Total sample area	**79 (3.3)**	**722 (29.7)**	**1,629 (67.0)**	**2,430**

Note: Figures in brackets are percentages.

[20] Respondents were told that when arsenicosis reaches an advanced stage, the cost of treatment would be about Tk 100,000. This is about 40 times the average monthly income of poor households (about Tk 2,300 per month).

afford the cost of treatment had relatively higher household incomes (Tk 10,896 per month on an average), those who said that it would be difficult to meet the cost had a lower average income (Tk 6,363 per month), and those who said that they would not be able to meet the cost at all had an average income of Tk 3,495 per month.

5.5 Perception of risk from arsenic-contaminated tubewells

Perception of risk from arsenic-contaminated tubewells was assessed in the context of whether households perceive this to be a serious threat to the health of the family given the serious health damages that the consumption of arsenic-contaminated water may cause and the high cost of treatment. As this issue is not relevant in the arsenic-free control area, responses were sought only from households in the arsenic-affected sample area.

Most households in Chandpur and Chapai Nawabganj considered arsenic contamination to be a serious threat to the family's health (Table 5.8).[21] In Barisal, while the majority of the respondents considered arsenic to be a serious threat (87 percent), a significant proportion (12.5 percent) said they were not sure or convinced that arsenic poses a serious threat. This may be because these households are from villages in Barisal where few tubewells have been tested and there are no known cases of arsenicosis.

5.6 Summing up

Most respondents in both the arsenic-affected and arsenic-free areas were aware of the arsenic problem. Information sources varied from awareness campaigns by field-based development organizations to the radio and television. However, few respondents in the arsenic-affected area were aware of the serious health effects of consuming arsenic-contaminated water and about half were not familiar with the symptoms of arsenicosis. Only about one-third of the respondents were aware that in the advanced stages, arsenicosis could result in gangrene or cancer, or even death.

Households in Chandpur were relatively more aware of the arsenic problem as there are higher incidence of arsenic-contaminated tubewells in the district and because the government and NGOs are organizing a number of activities to address the arsenic problem in the area.

Table 5.8: Perception of arsenic contamination as a serious threat to the family's health: Sample area

Given the health effects of arsenic contamination and the cost of treatment, is arsenic a serious threat to the health of the family?				
District	**Yes**	**No**	**Not sure, don't know**	**All**
Barisal	700 (86.7)	6 (0.7)	101 (12.5)	807
Chandpur	774 (99.5)	3 (0.4)	1 (0.1)	778
Chapai Nawabganj	826 (97.8)	2 (0.2)	17 (2.0)	845
Total	**2,300 (94.6)**	**11 (0.5)**	**119 (4.9)**	**2,430**

Note: Figures in brackets are percentages.

[21] There is a need for caution when drawing inferences from Table 5.8. During the interview, respondents were first asked whether they were aware that arsenic contamination could lead to cancer and gangrene, and then asked about affordability (to which most respondents replied that they would not be able to bear the cost of treatment at all). Both the questions and the replies were fresh in their mind when respondents were asked whether they considered arsenic contamination to be a serious threat. This may have prompted many respondents to say that they considered arsenic contamination to be a serious threat to their family's health though prior to the interview this was not a major concern.

6 Water Sources and Patterns of Use

The demand for alternative sources of water critically depends on the patterns of daily use of water in the household and perceptions of how safe and convenient current available sources are. Information was collected in the household and village surveys to assess daily household water consumption for drinking and cooking, the main sources of water, water quality and quantity, impact on health, changes in water sources, and whether households continue to consume water from contaminated sources after they have been tested and found unsafe. Detailed findings on water use and shifts in consumption patterns are discussed in this chapter.

6.1 Water consumption

The average daily water consumption per household was assessed by asking respondents to estimate their water use according to different activities in the dry and wet seasons. The results show that patterns of water consumption are more or less the same in both seasons. As can be seen from Table 6.1, in the dry season each household used an average of 339 liters of water daily in the sample area and 382 liters in the

Table 6.1: Water use in the dry season

Purpose	Barisal	Chandpur	Chapai Nawabganj	Total sample area	Total control area
Drinking	31.6	29.4	34.5	31.9	34.5
Cooking	56.0	44.6	50.3	50.4	46.0
Bathing	153.9	163.8	136.3	151.0	166.2
Others*	114.4	98.5	103.1	105.4	135.6
Total	**355.9**	**336.3**	**324.3**	**338.6**	**382.3**
Average family size	6.2	6.3	6.0	6.1	6.0
Per capita consumption	57.4	53.4	54.1	55.5	63.7

Note: Per capita water use has been calculated by dividing total daily use per household by average family size.
Figures are in liters per household per day.
** For instance, washing clothes.*

Table 6.2: Water use in the wet season

Purpose	Barisal	Chandpur	Chapai Nawabganj	Total sample area	Control area
Drinking	32.7	29.1	34.6	32.2	35.1
Cooking	58.0	44.6	50.3	51.0	44.6
Bathing	172.5	163.4	136.4	157.0	174.8
Others*	126.9	100.4	102.8	110.0	137.2
Total	**390.0**	**337.5**	**324.0**	**350.3**	**391.8**
Average family size	6.2	6.3	6.0	6.1	6.0
Per capita consumption	62.9	53.6	54.0	57.4	65.3

Note: Per capita water use has been calculated by dividing total daily use per household by average family size.
Figures are in liters per household per day.
** For instance, washing clothes.*

control area. Per capita water use[22] was about 56 liters per day in the sample area and 64 liters per day in the control area. In the wet season, per capita consumption per day was about 57 liters in the sample area and about 65 liters in the control area (see Table 6.2).

Patterns of water consumption for cooking and drinking were similar in the sample and control areas.[23] Each household used about 32 liters for drinking and 50 liters for cooking in the sample area. In the control area, the corresponding figures were 34 liters and 46 liters, respectively. Water used for other purposes was relatively higher in the control area (about 301 liters per household per day) than in the sample area (about 256 liters), possibly because the area surveyed in Commilla district is more developed than the other areas in the survey (Table 6.1). In fact, average water use in Commilla (427 liters per day) is comparatively higher than the average consumption in each of the three districts in the sample area (ranging from 324 to 356 liters) as well as in the control area of Chapai Nawabganj (337 liters).

6.2 Water sources

As can be seen from Tables 6.3 and 6.4, there is considerable similarity across households in terms of sources of water for drinking and cooking in the wet and dry seasons.

6.2.1 Drinking water

The survey results reveal that an overwhelming majority of households (about 93 percent in the sample area and 96 percent in the control area) accessed water for drinking from tubewells. This supports the estimates reported in earlier studies that around 97 percent of rural households in Bangladesh use groundwater sources for drinking water (WSP-SA, 2000). Both public tubewells and domestic (private) tubewells were being used. In the sample area, public tubewells were relatively more popular than domestic tubewells as a source of drinking water, with about 57 percent of the households using public tubewells, compared to 36 percent using domestic tubewells. In the control area, in contrast, more households were using domestic tubewells than water from public tubewells (about 76 percent and 20 percent,

[22] Calculated as daily water use per household divided by average family size.
[23] Data are presented here for the dry season; corresponding figures for water use in the wet season are listed in Table 6.2.

Table 6.3: Source of water for drinking and cooking in the dry season

Purpose	District	Sources of water								
		Dug-well (public)	Dug-well (private)	Pond/ tank	Tube-well (domestic)	Tube-well (public)	Canal/ stream	Piped water	Others	Total house-holds
Drinking	Barisal	0	1	23	143	653	7	0	0	807
	Chandpur	1	1	103	378	271	9	38	9	778
	Chapai Nawabganj	3	4	2	360	471	20	0	0	845
	Total sample area	**4 (0.2)**	**6 (0.2)**	**128 (5.3)**	**881 (36.3)**	**1,395 (57.4)**	**36 (1.5)**	**38 (1.6)**	**9 (0.4)**	**2,430**
	Control area	**4 (1.3)**	**3 (1.0)**	**3 (1.0)**	**229 (76.3)**	**60 (20.0)**	**1 (0.3)**	**0 (0.0)**	**0 (0.0)**	**300**
Cooking	Barisal	0	1	619	28	155	94	0	0	807
	Chandpur	0	0	728	10	3	48	2	3	778
	Chapai Nawabganj	1	3	123	256	136	359	0	0	845
	Total sample area	**1 (0.0)**	**4 (0.2)**	**1,470 (60.5)**	**294 (12.1)**	**294 (12.1)**	**501 (20.6)**	**2 (0.1)**	**3 (0.1)**	**2,430**
	Control area	**0 (0.0)**	**0 (0.0)**	**101 (33.7)**	**133 (44.3)**	**34 (11.3)**	**57 (19.0)**	**0 (0.0)**	**0 (0.0)**	**300**

Note: Some households reported using multiple sources.
Figures in brackets are percentages.

Table 6.4: Source of water for drinking and cooking in the wet season

Purpose	District	Sources of water								
		Dug-well (public)	Dug-well (private)	Pond/ tank	Tube-well (domestic)	Tube-well (public)	Canal/ stream	Piped water	Others	Total house-holds
Drinking	Barisal	1	0	20	146	651	8	0	1	807
	Chandpur	1	1	107	382	258	7	39	36	778
	Chapai Nawabganj	2	4	3	360	470	21	0	0	845
	Total sample area	**4 (0.2)**	**5 (0.2)**	**130 (5.3)**	**888 (36.5)**	**1,379 (56.7)**	**36 (1.5)**	**39 (1.6)**	**37 (1.5)**	**2,430**
	Control area	**5 (1.7)**	**3 (1.0)**	**2 (0.7)**	**231 (77.0)**	**59 (19.7)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**300**
Cooking	Barisal	0	0	624	28	142	87	0	1	807
	Chandpur	0	0	730	8	6	39	2	37	778
	Chapai Nawabganj	1	3	122	254	133	367	0	1	845
	Total sample area	**1 (0.0)**	**3 (0.1)**	**1,476 (60.7)**	**290 (11.9)**	**281 (11.6)**	**493 (20.3)**	**2 (0.1)**	**39 (1.6)**	**2,430**
	Control area	**1 (0.3)**	**0 (0.0)**	**102 (34.0)**	**133 (44.3)**	**33 (11.0)**	**56 (18.7)**	**0 (0.0)**	**1 (0.3)**	**300**

Note: Some households reported using multiple sources.
Figures in brackets are percentages.

respectively).[24] Of the households using surface water sources, about 5 percent in the sample area and 1 percent in the control area were using water from ponds or tanks while 1.5 percent and 0.3 percent, respectively, were using water from canals and streams.

A few households in the sample area (about 1.6 percent) were accessing drinking water from piped water supply schemes. These households were, however, concentrated in certain pockets where such networks exist.[25]

6.2.2 Water for cooking

Most households (about 80 percent in the sample area and 53 percent in the control area) were using surface water sources such as ponds, tanks, canals or streams for cooking. While about 60 percent of the households in the sample area and 34 percent in the control area were using water from ponds and tanks, about 21 percent in the sample area and about 19 percent in the control area were using water from canals and streams.[26] Tubewells were more commonly used in the arsenic-free control area as a source of water for cooking. In the control area, about 56 percent of the households were using tubewell water as compared to 24 percent in the sample area.

6.3 Water quantity and quality

Information was sought on respondents' perceptions of the quantity and quality of water being consumed. While most households were satisfied with the quantity of water available (Table 6.5), some households (about 15 percent in the sample area and 5 percent in the control area) were not entirely satisfied, and a few households (1.5 percent in the sample area and 0.3 percent in the control area) were dissatisfied.

Households reporting that they were dissatisfied or not entirely satisfied with the quantity of water available were asked to estimate their additional water requirements. On an average, the shortfall was about 40 liters per household per day in the dry season and 35 liters per household per day in the wet season, which is about 10 percent of the current household consumption level.

Respondents were also asked whether they faced problems with regard to the quality of drinking water. Most households in the sample area (about 72 percent) did not report any water quality problems (Table 6.6). However, about 12 percent (mostly in Chapai Nawabganj) complained that the water had a high iron content, 11 percent (most of whom were from Chandpur) reported arsenic contamination, and

Table 6.5: Reported satisfaction with the quantity of water available from current water sources

District	Household satisfaction with water quantity			
	Satisfied	Not entirely satisfied	Dissatisfied	Total
Barisal	545	249	13	807
Chandpur	649	106	23	778
Chapai Nawabganj	837	8	0	845
Total sample area	**2,031 (83.6)**	**363 (14.9)**	**36 (1.5)**	**2,430**
Control area	**285 (95.0)**	**14 (4.7)**	**1 (0.3)**	**300**

Note: Figures in brackets are percentages.

[24] The discussion here covers the dry season; figures for the wet season are similar.
[25] The majority of households using piped water were from a particular village in Chandpur district, which is adjacent to a small town and has access to public standposts.
[26] These figures are for the dry season; figures for the wet season are similar.

4 percent reported that the water was turbid or had a foul smell.

In the control area, about 43 percent of the households reported that they did not face any water quality problems. However, the majority of households (about 54 percent) mentioned high iron content in the drinking water and about 3 percent complained of turbidity.

About 72 percent of the households in the sample area reported that they did not face any problem with the quality of water used for cooking (Table 6.7). Some households reported problems of turbidity (about 16 percent), foul smell (about 5 percent), and high iron content (3.5 percent). These problems were also mentioned for water being used for purposes other than drinking and cooking (bathing and washing clothes).

In the control area, about 45 percent of the households reported that they faced no problem with the quality of water used for cooking (Table 6.7). Some households (about 28 percent) reported problems of turbidity, high iron content (21 percent), and foul smell (5 percent). These problems were also mentioned, though to a lesser extent, with regard to water being used for purposes other than drinking and cooking.

6.4 Water quality and the incidence of diarrhea

An important issue in the context of water quality is its impact on health, particularly the incidence of diarrhea. Questions were included in the household survey to gather data on the occurrence of diarrhea in the family in the past two weeks and the past six months, the cost of treatment, and the possible cause of infection.

Table 6.6: Reported satisfaction with the quality of drinking water

District	Reported water quality problem						
	No problem	Turibid	Foul smell	High iron content	Saline	Arsenic-contaminated	Others
Barisal	717	20	10	48	7	3	2
Chandpur	459	37	19	38	3	216	6
Chapai Nawabganj	573	7	5	206	2	51	1
Total sample area	**1,749 (72.0)**	**64 (2.6)**	**34 (1.4)**	**292 (12.0)**	**12 (0.5)**	**270 (11.1)**	**9 (0.4)**
Control area	**129 (43.0)**	**8 (2.7)**	**1 (0.3)**	**162 (54.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**

Note: Figures in brackets are percentages.

Table 6.7: Reported satisfaction with the quality of water for cooking and other purposes

Problem	Water used for cooking		Water used for purposes other than drinking and cooking	
	Sample area	Control area	Sample area	Control area
No problem	1,751 (72.0)	136 (45.3)	1,933 (79.5)	244 (81.3)
Turbid	395 (16.3)	83 (27.7)	302 (12.4)	37 (12.3)
Foul smell	117 (4.8)	15 (5.0)	52 (2.1)	1 (0.3)
High iron content	85 (3.5)	64 (21.3)	66 (2.7)	18 (6.0)
Others	82 (3.4)	2 (0.7)	77 (3.2)	0 (0.0)
Total households	**2,430**	**300**	**2,430**	**300**

Note: Figures in brackets are percentages.

About 6 percent of the households in both the sample and control areas reported that in the two weeks prior to the interview, there had been at least one case of diarrhea in the family while 16 percent reported cases of diarrhea in the previous six months (Table 6.8). The proportion of children affected was significant. Approximately a quarter of the cases of diarrhea reported over the past six months were infants up to 5 years and one-third were between 6-14 years. About 46 percent of the cases over the past six months were persons above 15 years.

Of the 2,730 households surveyed in the sample and control areas, 432 households (or 16 percent) reported cases of diarrhea in the family in the previous six months. The number of episodes reported was about 2 per household (typically of six members). The expenditure incurred on treatment per episode was about Tk 160, and the loss of human-days per episode was about 1.5.

Most households did not associate the incidence of diarrhea with contaminated water (Table 6.9). Only 20 percent associated diarrhea with contaminated sources of drinking water or the contamination of water during transportation or storage (8 percent).

6.5 Shift to alternative safe water sources

To establish a link between arsenic contamination and moving to alternative safe water sources, respondents were asked whether they had shifted their water source in the last three years and the reason for making the change. Findings with regard to alternate sources of drinking water and water for cooking are presented in this section.

6.5.1 Drinking water

In the sample area, about 30 percent of the households had changed their drinking water source in the past three years compared to only about 4 percent in the control area (Table 6.10). A district-wise comparison shows that this shift has been greatest in Chandpur (54 percent), followed by Barisal (25 percent), and Chapai Nawabganj (13 percent).

Table 6.8: Reported cases of diarrhea in the sample and control areas

	Households reporting diarrhea (%)	Number of cases reported per household	Age distribution of reported cases (%)		
			Up to 5 years	6-14 years	15 years & above
Previous two weeks	6	0.5	33	25	42
Previous six months	16	1.9	23	31	46

Note: Figures have been combined for the sample and control areas.

Table 6.9: Respondents reporting causes of diarrhea in the sample and control areas

Reason	Number of households	Percentage
Water contamination at source	87	20
Water contamination during collection/transportation	9	2
Water contamination during storage (unclean vessel)	27	6
Others*	233	54
Cause not known	76	18
Households reporting cases of diarrhea in the family	432	100

** For instance, eating stale/contaminated food, or indigestion.*

Table 6.10: Change in drinking water source

District	Change in source		
	Yes	No	Total
Barisal	202 (25.0)	605 (75.0)	807
Chandpur	419 (53.9)	359 (46.1)	778
Chapai Nawabganj	109 (12.9)	736 (87.1)	845
Total sample area	**730 (30.0)**	**1,700 (70.0)**	**2,430**
Control area	**11 (3.7)**	**289 (96.3)**	**300**

Note: Figures in brackets are percentages.

Table 6.11: Households reporting a change in their drinking water source in the past three years

District	Earlier source					
	Tubewell (Domestic)	Tubewell (Public)	Pond/ Tank	Piped water	Others	Total
Barisal	165	24	5	1	7	202
Chandpur	367	35	6	1	10	419
Chapai Nawabganj	61	44	0	0	4	109
Total sample area	**593 (81.2)**	**103 (14.1)**	**11 (1.5)**	**2 (0.3)**	**21 (2.9)**	**730**
Control area	**5 (45.5)**	**5 (45.5)**	**1 (9.0)**	**0 (0.0)**	**0 (0.0)**	**11**
District	**Current source**					
	Tubewell (Domestic)	Tubewell (Public)	Pond/ Tank	Piped water	Others	Total
Barisal	8	189	4	0	1	202
Chandpur	60	176	60	33	90	419
Chapai Nawabganj	48	59	0	0	2	109
Total sample area	**116 (15.9)**	**424 (58.1)**	**64 (8.8)**	**33 (4.5)**	**93 (12.7)**	**730**
Control area	**11 (100)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**11**

Note: Figures in brackets are percentages of the total number of households that changed drinking water source.

There is no uniform pattern among the households that have shifted to an alternate water supply (Table 6.11). While, in the control area, almost every household shifted from public tubewells to private tubewells, the reverse was true of the sample area, where about half the households shifted from private tubewells to public tubewells. Some households shifted to other drinking water sources. In the sample area, for instance, about 7 percent shifted from public tubewells to domestic tubewells, another about 7 percent shifted from private tubewells to ponds or tanks, 4 percent shifted to piped water, and 9 percent shifted to other sources. (This is reflected in the difference between the percentage figures in brackets for the earlier source and the present source in Table 6.11).

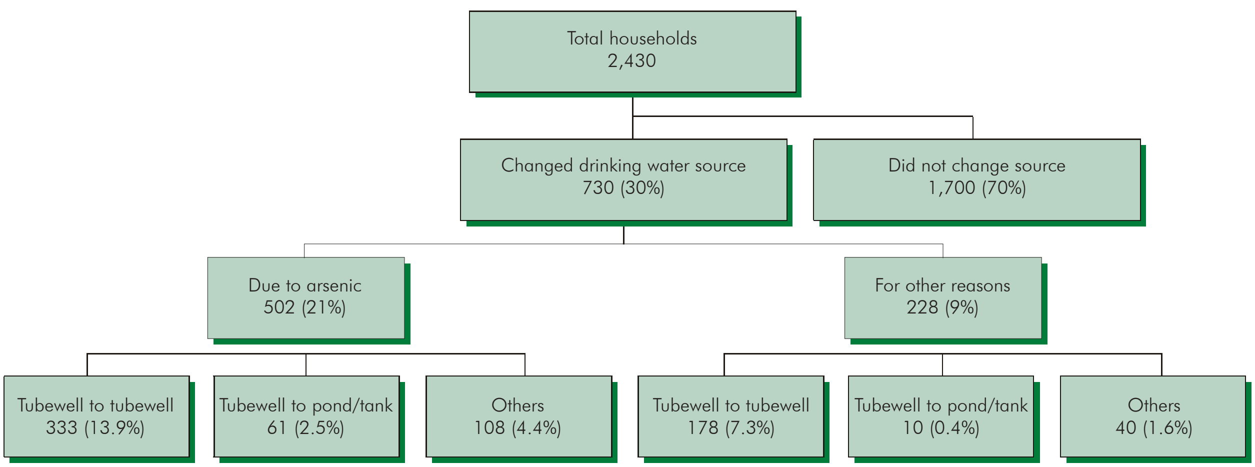
The survey also sought to determine the extent to which source changing is influenced by arsenic contamination. Most households (69 percent) in the arsenic-affected sample area that had changed their source of water supply stated that the main reason for change was that the earlier drinking water source was

Table 6.12: Reasons for households changing their drinking water source

Reason	Barisal	Chandpur	Chapai Nawabganj	Sample area	Control area
Earlier source no longer available or inadequate	20	18	8	46 (6.3)	2 (18.2)
Earlier source arsenic-contaminated	98	338	66	502 (68.8)	0 (0.0)
New source more convenient/nearer house	27	25	18	70 (9.6)	8 (72.7)
New source provides water better in taste	63	10	5	78 (10.7)	1 (9.1)
New source provides water cleaner in appearance	33	14	7	54 (7.4)	1 (9.1)
Installed own tubewell	0	3	15	18 (2.5)	0 (0.0)
Others	10	49	22	81 (11.1)	0 (0.0)

Note: Multiple responses were considered.
Figures in brackets are percentages.

Figure 6.1: Distribution of households in the sample area according to changes in drinking water source



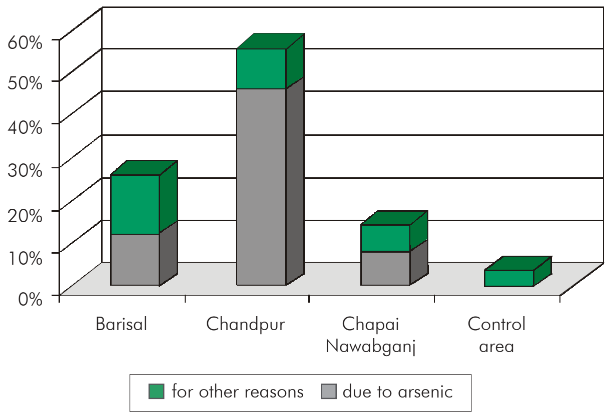
arsenic-contaminated (Table 6.12; Figure 6.1).[27] This is also reflected in district-wise figures (see Figure 6.2). In Chandpur, about 83 percent of the households made a change because the source was contaminated with arsenic; the corresponding figures for Chapai Nawabganj and Barisal are 61 percent and 49 percent, respectively. In the arsenic-free control area, contamination of the source was naturally not a reason for change.

For about 31 percent of households in the sample area that changed their drinking water source, the decision to adopt a new water source was not linked to the arsenic problem. Among the reasons cited were convenience of the new source, non-availability of the earlier source, inadequate water supply, and physical properties, such as appearance and taste.

Shifting to an alternative source of water has involved walking longer distances to collect drinking water (Table 6.13). Taking an average of all the households that have changed their drinking water source in the three years prior to the survey in the sample and control areas, the distance travelled to

[27] Most households in the sample area that had changed their source due to arsenic contamination had shifted from one tubewell to another (66 percent). Approximately 79 percent had shifted from a domestic tubewell to a public tubewell, 12 percent had shifted from one domestic tubewell to another, 6 percent had shifted from one public tubewell to another, and 3 percent had shifted from a public tubewell to a domestic tubewell.

Figure 6.2: Proportion of households that have changed their drinking water source due to arsenic contamination and other reasons



collect water has increased from 113 feet to 503 feet while the average time spent has increased from 11 minutes to 25 minutes. Each family now spends, on an average, an additional 14 minutes every day fetching drinking water. Among the households in the sample area that have changed their drinking water source due to arsenic contamination, the average distance has gone up from 84 feet to 556 feet and the average time spent to collect drinking water has increased from 9 to 27 minutes. Thus, these households are spending, on average, an additional 18 minutes each day to collect drinking water.

The fact that the increase in the average time spent in collecting water has been less than proportionate to the increase in the average distance can be explained by the increased number of safe drinking water sources over the years so that the time spent in queues has come down. Another possible reason is that if the new source is further away, people may make fewer trips to the source to collect water, thus leading to some saving of time.

6.5.2 Water for cooking

Compared to households that had changed their drinking water source, few households (3 percent in the sample area and 1 percent in the control area) had changed their source of water for cooking (Table 6.14).

In the control area, most households had changed from surface water sources, such as ponds and tanks, to tubewells (Table 6.15). In the sample area, the

Table 6.13: Impact of the new source of drinking water

District	New source far away		Need more time to fetch water	
	Yes	No	Yes	No
Chapai Nawabganj	55	54	55	54
Barisal	151	51	151	51
Chandpur	344	75	344	75
Total sample area	**550**	**180**	**550**	**180**
Control area	**2**	**9**	**2**	**9**

Table 6.14: Change in source of water for cooking (number of households)

District	Change in source	
	Yes	No
Barisal	25 (3.1)	782 (96.9)
Chandpur	14 (1.8)	764 (98.2)
Chapai Nawabganj	45 (5.3)	800 (94.7)
Total sample area	**84 (3.3)**	**2,346 (96.5)**
Control area	**3 (1.0)**	**297 (99.0)**

Note: Figures in brackets are percentages.

Table 6.15: Earlier source and current source of water for cooking

District	Tubewell (Domestic)	Earlier source			
		Tubewell (Public)	Piped water	Pond/tank	Other
Barisal	11	4	1	7	2
Chandpur	6	0	0	8	0
Chapai Nawabganj	16	26	0	0	3
Total sample area	**33 (39.3)**	**30 (35.7)**	**1 (1.2)**	**15 (17.9)**	**5 (5.9)**
Control area	**0 (0.0)**	**1 (33.3)**	**0 (0.0)**	**2 (66.7)**	**0 (0.0)**
District	**Tubewell (Domestic)**	**Current source**			
		Tubewell (Public)	**Piped Water**	**Pond/tank**	**Other**
Barisal	3	14	0	8	0
Chandpur	0	1	2	7	4
Chapai Nawabganj	30	12	0	0	3
Total sample area	**33 (39.3)**	**27 (32.1)**	**2 (2.4)**	**15 (17.9)**	**7 (8.3)**
Control area	**3 (100)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**

Note: In all, 84 households in the sample area and 3 in the control area have changed their source of water for cooking (see Table 6.14). Figures in brackets are percentages of the total number of households that have changed their drinking water source in each area.

Table 6.16: Reasons for changing to a new source of water for cooking

Reason	Barisal	Chandpur	Chapai Nawabganj	Sample area	Control area
Earlier source not available or inadequate	3	0	1	4 (4.8)	0 (0.0)
Earlier source arsenic-contaminated	4	6	10	20 (23.8)	0 (0.0)
New source more convenient/nearer house	8	2	22	32 (38.1)	3 (100)
New source provides water better in taste	9	3	1	13 (15.5)	0 (0.0)
New source provides water cleaner in appearance	2	0	1	3 (3.6)	0 (0.0)
Installed own tubewell	1	1	12	14 (16.7)	0 (0.0)
Other reasons	2	4	5	11 (13.1)	0 (0.0)

Note: Multiple responses were considered.
Figures in brackets are percentages.

change was generally from one tubewell to another. In Chapai Nawabganj, a number of households had shifted from public to private tubewells. In Barisal, in contrast, a number of households had shifted from private to public tubewells.

The main reasons cited for changing the source of water for cooking were that the earlier source was arsenic-contaminated or that a new, more convenient source was available (Table 6.16).

6.6 Testing of tubewells for arsenic contamination reported by households

In the survey, households were asked whether the tubewell nearest to their house (owned by them or accessible to them) had been tested for arsenic contamination, the test result, whether they were continuing to use water from tubewells that had tested positive for arsenic contamination, and the reasons for their continued use.

Most households in the sample area (58 percent) reported that the tubewell nearest to their house had been tested for arsenic. In the control area, however, less than 1 percent reported such a test (see Table 6.17). These findings indicate that while most of the tubewells in the arsenic-affected areas had been tested, a sizeable portion still remained to be investigated.

There were marked inter-district variations in the sample area. While about 88 percent of the households in Chandpur reported that the tubewells owned by or accessible to the household had been tested, the corresponding figures were significantly lower for Chapai Nawabganj and Barisal (49 percent and 40 percent, respectively) (Figure 6.3).

According to information provided by the households, in the sample area as a whole, 61 percent of the tested tubewells were contaminated. District-wise figures reveal that over 90 percent of the tested tubewells in Chandpur were contaminated (Table 6.17, Figure 6.4). The proportion was much lower in the arsenic-affected areas of Barisal (41 percent) and Chapai Nawabganj (23 percent).

About 35 percent of the households in the sample area had encountered the problem of arsenic contamination in the tubewell owned by or accessible to them, and 59 percent of these households (about 20 percent of the total sample) had shifted to

Figure 6.3: Percentage of tubewells tested for arsenic in the sample area

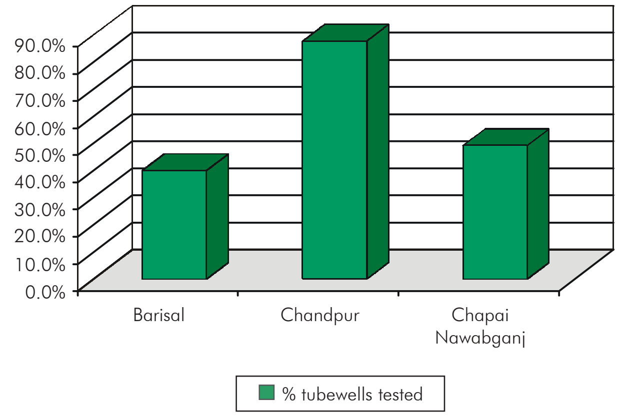


Figure 6.4: Percentage of tested tubewells found to be arsenic-contaminated in the sample area

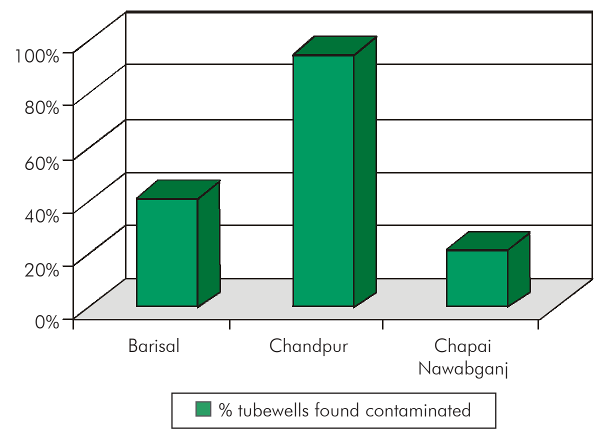


Table 6.17: Household-based information on the testing of tubewells for arsenic contamination nearest to their homes

District	Tubewell tested for arsenic			Test result		Currently using contaminated tubewell for drinking and/or cooking	
	Yes	No	Don't know	Arsenic contaminated	Arsenic free	Yes	No
Barisal	322 (39.9)	415 (51.4)	70 (8.7)	131 (40.7)	191 (59.3)	17 (13.0)	114 (87.0)
Chandpur	682 (87.7)	84 (10.8)	12 (1.5)	639 (93.7)	43 (6.3)	280 (43.8)	359 (56.2)
Chapai Nawabganj	416 (49.2)	427 (50.5)	2 (0.2)	96 (23.1)	320 (76.9)	60 (62.5)	36 (37.5)
Total sample area	**1,420 (58.4)**	**926 (38.1)**	**84 (3.5)**	**866 (61.0)**	**554 (39.0)**	**357 (41.2)**	**509 (58.8)**
Control area	**2 (0.7)**	**296 (98.6)**	**2 (0.7)**	**0 (0.0)**	**2 (100)**	–	–

Note: Figures relate to tubewells owned by or accessible to households covered in the survey.
Figures in brackets are percentages.

alternate safe sources. However, the remaining 41 percent (about 15 percent of the total sample) were continuing to use contaminated tubewells, in the majority of cases because of the lack of a suitable alternate source (Table 6.18, Figures 6.5 and 6.6). In a few cases (1 percent of the total sample), the respondents said that they were unconcerned about the consequences of arsenic poisoning or they felt that there was only a remote possibility of their family members being affected by arsenic.

Of the 866 tubewells found to be arsenic-contaminated in the sample area, 357 (41 percent) were still being used to draw water for drinking and/or cooking. District-wise figures show that in Chapai Nawabganj a significant number (about 63 percent) of the tubewells found to be arsenic-contaminated were being used. In Chandpur, 44 percent of the contaminated tubewells were being used, while in Barisal most of the contaminated tubewells were not being used (Figure 6.7).

Table 6.18: Reasons for continued use of contaminated wells in the sample area (number of respondents)

Reason	Barisal	Chandpur	Chapai Nawabganj	Sample area
No suitable alternate source available	17	248	52	317 (88.8)
Not considered the consequences of using arsenic-contaminated water	0	4	0	4 (1.1)
Unconcerned about arsenic poisoning	0	5	2	7 (2.0)
Feel that the chance of family members being affected by arsenic in water is remote since they have been using it for a long time	0	15	3	18 (5.0)
Many other families are doing so	0	3	0	3 (0.8)
Others	–	5	3	8 (2.2)
Total	**17**	**280**	**60**	**357 (100)**

Figure 6.5: Number of tubewells tested for arsenic, test results, and reasons for continued use of contaminated tubewells

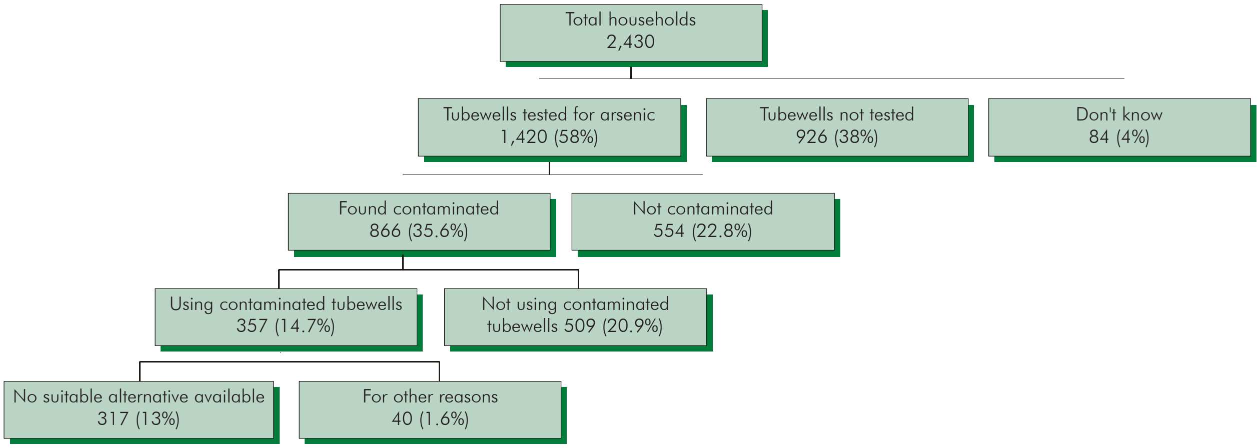


Figure 6.6: Reasons for continuing to use contaminated tubewells

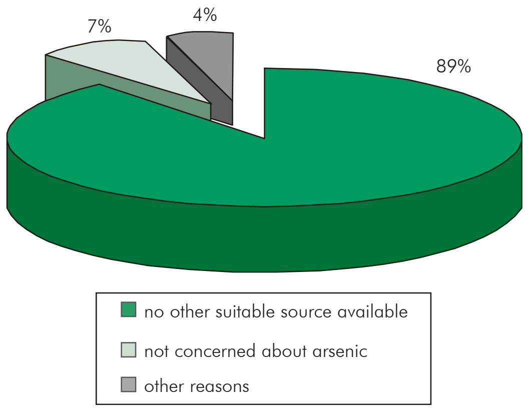
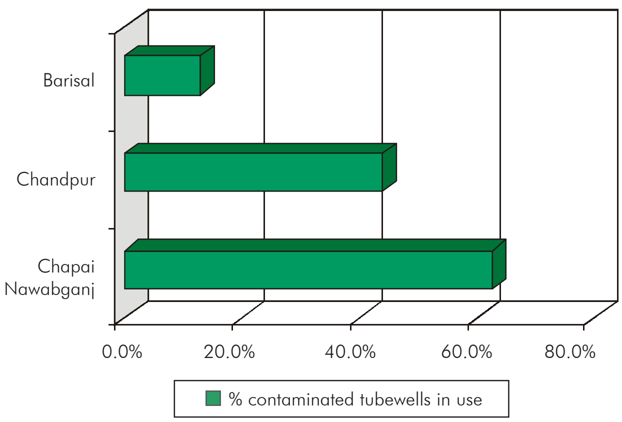


Figure 6.7: Percentage of contaminated tubewells currently in use in the sample area



The inter-district differences in the results of the survey on the testing of tubewells and the continued use of contaminated tubewells require analyses. Table 6.17 clearly shows that many more tubewells have been tested for arsenic in Chandpur than in Barisal and Chapai Nawabganj. This can be explained by the larger extent of arsenic mitigation-related activities in Chandpur compared to the other two districts. Table 6.17 also shows that the incidence of arsenic-contaminated tubewells is greater in Chandpur than in Chapai Nawabganj and Barisal. This is consistent with the survey finding of a larger number of cases of arsenicosis in Chandpur compared to the other two districts (see Table 5.3).

The incidence of arsenic-contaminated tubewells is lowest in Chapai Nawabganj, but the shift to safe water sources is also lowest in this district. One reason could be that the cost of sinking a tubewell is considerably higher in Chapai Nawabganj because the hydrogeological conditions are not as favorable as in the other districts. As a result, households would naturally be reluctant to shift to another drinking water source after making such a substantial investment. Moreover, the government has initiated a large-scale arsenic-eradication program in Chandpur (promoting the installation of deep tubewells), which is virtually absent in Chapai Nawabganj.

In spite of the relatively greater shift to safe water sources in Chandpur, the proportion of households that continue to use contaminated tubewells for drinking water is higher in this district compared to Barisal and Chapai Nawabganj (36 percent in Chandpur and only 2 percent in Barisal and 7 percent in Chapai Nawabganj).

6.7 Summing up

Private and public tubewells were the main source of drinking water in rural areas while surface water sources, such as ponds and tanks, were the main source of water for cooking. Most respondents were satisfied with the quantity of water they could access, although many of them reported problems such as turbidity, foul smell, and high iron content. A significant number of respondents in Chandpur mentioned the presence of arsenic in their drinking water.

About 30 percent of the respondents in the sample area said that they had changed their drinking water source in the last three years. Most people had shifted from private tubewells to public tubewells. In some cases, households had changed from private tubewells to ponds or tanks. The main reason for shifting to a new source was because the previous source was arsenic-contaminated.

According to information provided by households in the sample area, more than half the tubewells owned by or accessible to them had been tested and about 60 percent were found to be contaminated. However, a significant number of tubewells known to be contaminated continued to be in use, mainly because the households did not have a suitable alternative safe source of drinking water.

The findings of the household survey on the testing of tubewells and the use of contaminated tubewells are corroborated by the data collected through the village questionnaire. Village-level data indicate that more than half the tubewells in the villages in the sample area had been tested for arsenic and were found to be contaminated, and a significant proportion continued to be used for drinking and cooking.

The incidence of arsenic-contaminated tubewells was highest in Chandpur and lowest in Chapai Nawabganj. The shift to safe water sources from arsenic-contaminated tubewells was highest in Barisal, followed by Chandpur, and Chapai Nawabganj. A significant proportion of rural households in Chandpur (about one-third) continued to use arsenic-contaminated water for drinking and/or cooking even after the substantial shift to safe water sources. This ratio is relatively small in the other two districts.

7 Household Preferences among Arsenic Mitigation Technologies

Unlike earlier studies that focused mainly on the technology aspect of arsenic treatment units and other arsenic-safe water options, and their effectiveness, an important objective of the study on Bangladesh was to evaluate people's preferences among selected arsenic mitigation technologies[28] currently being field-tested in the country. Six technologies were chosen for the study: the three-*kolshi* (pitcher) method, the household-based activated alumina method, the community-based activated alumina method, dugwells, pond sand filters, and deep tubewells (more specifically, manually operated deep tubewell handpumps). These technologies represent both arsenic reduction units (the three-*kolshi* and activated alumina methods) as well as technologies that make use of alternate safe water sources (dugwells, pond sand filters, and deep tubewells).[29] The technologies were carefully selected based on the findings of earlier studies in terms of their effectiveness in mitigating arsenic and how communities responded to them in the course of field trials (BRAC, 2000; BAMWSP, DFID, and WaterAid Bangladesh, 2001).

Information on consumer preferences is crucial to design user-friendly schemes to be implemented in the future. Details were sought on whether households would be willing to pay for and use one or more of the selected technologies and how they would rank the technologies based on their effectiveness in mitigating arsenic, convenience of use, associated risks, and capital and recurring cost. Questions on the selected technologies were canvassed only in the arsenic-affected sample area, as these issues do not impact households in the arsenic-free control area.

[28] For the purpose of this study, arsenic mitigation technologies are defined broadly as technologies that treat arsenic-contaminated tubewell water as well as those that enable households to access arsenic-safe water sources.
[29] These six technologies will hereafter be referred to as the selected arsenic mitigation technologies or the six selected technologies.

Table 7.1: Respondents' knowledge of selected arsenic mitigation technologies

District	Had used or were using any of the six selected technologies	
	Yes	No
Barisal	634 (78.6)	173 (21.4)
Chandpur	243 (31.2)	535 (68.8)
Chapai Nawabganj	38 (4.5)	807 (95.5)
Total sample area	**915 (37.6)**	**1,515 (62.3)**

Note: Figures in brackets are percentages.

Table 7.2: Respondents who had used or were using the selected arsenic mitigation technologies

Technology	Number of respondents who have used or are using the technology
Activated alumina	5 (0.5)
Deep tubewell	891 (97.4)
Dugwell	5 (0.5)
Pond sand filter	2 (0.2)
Three-*kolshi*	20 (2.2)
Total sample area	**915**

Note: Figures in brackets are percentages.
Some respondents had used more than one technology.

7.1 Knowledge of arsenic mitigation technologies

The field survey indicates that about 38 percent of the respondents had used or were currently using one or more of the six selected arsenic mitigation technologies (Table 7.1). Among them, the overwhelming majority (97 percent) had used or were using deep tubewells (Table 7.2). Other technologies being used (though to a limited extent) were the three-*kolshi* method (2 percent), activated alumina units (0.5 percent), dugwells (0.5 percent), and pond sand filters (0.2 percent).

Some of the problems related to using arsenic mitigation technologies were low water flow, clogging of the filter, uncertainty of safe limits of arsenic removal, high recurring cost, and problems in maintenance (Box 7.1).[30] The most common complaint with regard to government-constructed deep tubewells was the distance a person had to walk to collect water.[31]

7.2 Preferences among arsenic mitigation technologies

7.2.1 Community-based versus household-based technologies

As only a small section of households in the arsenic-affected areas had used or were currently using any of the six selected technologies, or were familiar with only one or two technologies, respondents were

[30] Similar problems were noted in other studies (BAMWSP, DFID, WaterAid, 2001; BRAC, 2000).
[31] The problems with deep tubewells require special mention because these are the most widely used of the selected technologies in Bangladesh. Also, as seen later, this technology was reported to be the most preferred by households in the sample area.

briefed about the six technologies and the advantages and limitations of each. Issues such as the quantity of water that would be available for a family in a day with each technology, conveniences and risks, and the associated capital and O&M cost were discussed. Respondents were informed that by using household-based technologies, for instance, they would get safe water within the household but they would also be responsible for operating and maintaining the unit as well as for the safe disposal of the sludge. Choosing a community-based technology would mean that they would have to fetch water from outside the house, but would be spared these responsibilities. After the respondents were briefed, they were asked whether they would choose household-based arsenic mitigation units or community-based ones keeping in mind the convenience factor rather than cost.

Box 7.1

Reported problems of arsenic mitigation technologies

THREE-*KOLSHI* METHOD

- Low rate of water flow
- Clogging of filter
- Water is not available immediately — one has to wait

ACTIVATED ALUMINA METHOD

- Cannot be sure that arsenic has been removed to a safe limit
- Difficulty in getting chemicals, etc., to operate the technologies
- Water does not taste good
- High operation and maintenance cost
- Difficult to use/maintain

DUGWELL

- Bacteriological contamination is not adequately addressed
- Needs to be kept in a sanitary condition
- Water does not taste good

DEEP TUBEWELL

- Have to go far to collect water
- One has to wait to get water
- For those owning deep tubewells, the initial capital cost is high
- Water does not taste good
- Water is sometimes dirty

Survey data revealed that, based on considerations of risk and convenience (disregarding capital and recurring cost), the dominant preference was for community-based technologies (72 percent) rather than household-based units (28 percent) (Table 7.3).[32]

Table 7.3: Household preferences among arsenic mitigation technologies

District	Number of households preferring			Number of household preferring		
	Household-based technology	Community-based technology	Indifferent	Tubewell-based water source	Alternate safe water source	Indifferent
Barisal	121 (15.0)	685 (84.9)	1 (0.1)	106 (13.1)	698 (86.5)	3 (0.4)
Chandpur	224 (28.8)	552 (70.9)	2 (0.3)	285 (36.6)	491 (63.1)	2 (0.3)
Chapai Nawabganj	326 (38.6)	514 (60.8)	5 (0.6)	676 (80.0)	165 (19.5)	4 (0.5)
Total sample area	**671 (27.6)**	**1,751 (72.1)**	**8 (0.3)**	**1,067 (43.9)**	**1,354 (55.7)**	**9 (0.4)**

Note: Figures in brackets are percentages.

[32] The finding that rural households prefer community-based arsenic mitigation technologies to household-based ones lends support to earlier studies on the subject. According to one report, "Some stakeholders have expressed doubts about the viability of 'household' arsenic units, and have suggested that 'community' arsenic removal units are preferable. They note the difficulties associated with persuading millions of households to use arsenic removal units, and ensuring that they are used reliably, and the advantages of centralized operation and maintenance, including arsenic testing, by trained caretakers" (WSP-SA, 2000:14). It should be noted that from the point of view of a typical household, arsenic mitigation technologies are new, and hence risky. A household will, therefore, probably have a lower preference for household-based technologies as this involves individual risk. Community-based technologies involving community efforts and shared risks would have greater appeal.

7.2.2 Arsenic removal technology versus an alternate safe water source

Respondents were asked whether they would prefer a technology that purifies arsenic-contaminated tubewell water or an alternate source of safe water after considering the risks associated with each technology. Technologies that treat tubewell water, for instance, require perfect, timely and thorough maintenance of the equipment to ensure that the level of arsenic is continually and effectively reduced to an acceptable level. Water quality also needs to be periodically monitored if safe drinking water is to be supplied. Water supply from an alternate source, in contrast, may have problems of bacteriological contamination or may not taste good. The findings show that about 56 percent of the respondents preferred alternate safe water sources to a technology that purifies arsenic-contaminated tubewell water (Table 7.3).

There were significant inter-district variations in this regard. In Chapai Nawabganj, there was a strong preference for technologies that treat tubewell water, while in Barisal and Chandpur households generally favored alternate safe water sources. This difference could be explained by the fact that it is relatively more expensive to install a tubewell in Chapai Nawabganj, so after a household has invested in a tubewell they would naturally be more interested in a technology that would allow them to continue to use this source.

7.3 Willingness to pay for a technology of choice

After considering the capital and recurring cost of the six arsenic mitigation technologies, as well as the advantages and disadvantages of each, about 76 percent of the respondents expressed a willingness to pay for the use of one or more of these technologies (Table 7.4, Figure 7.1). The ratio was 74 percent among poor and 80 percent among non-poor households. Respondents who were not willing to pay for any of the selected arsenic mitigation technologies (24 percent) said that they could not afford the cost of the technology (44 percent) or that they were satisfied with the current water quality (29 percent) (Table 7.5, Figure 7.2).

Comparing responses across districts, unwillingness to pay for any of the selected technologies was relatively higher in Barisal (37 percent) than in Chandpur (24 percent) and Chapai Nawabganj (11 percent). In Chapai Nawabganj, most households were not willing to pay for arsenic mitigation technologies because they could not afford them while in Barisal, the primary reason was satisfaction with the current water quality (Table 7.5).

Figure 7.1: Willingness to pay for and use arsenic mitigation technologies

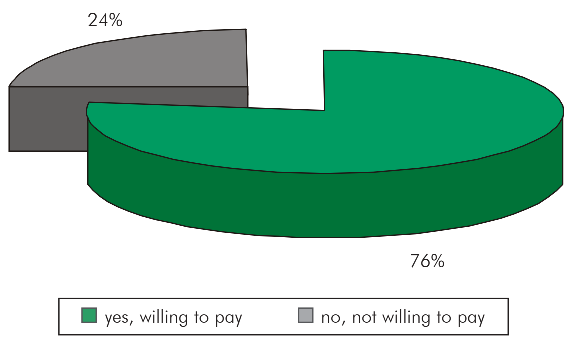


Figure 7.2: Reasons for unwillingness to pay for and use arsenic mitigation technologies

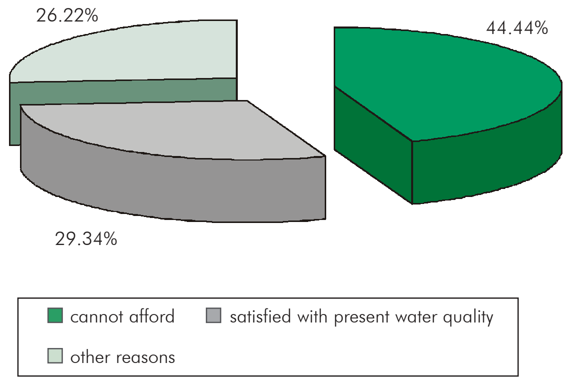


Table 7.4: Choice of alternative arsenic mitigation technologies

District	Willing to pay and use arsenic mitigation technologies		If yes, mention first & second choices First choice					
	Yes	No	Three-*kolshi*	Act. Alum. (H)	Act. Alum. (C)	Dugwell	PSF	Deep tubewell
Barisal	510	297	28	4	5	10	11	445
Chandpur	588	190	122	51	13	14	11	375
Chapai Nawabganj	756	89	141	33	43	20	7	510
Total	**1,854 (76.3)**	**576 (23.7)**	**291 (15.8)**	**88 (4.8)**	**61 (3.3)**	**44 (2.4)**	**29 (1.6)**	**1,331 (72.2)**
District			**Second choice**					
			Three-*kolshi*	Act. Alum. (H)	Act. Alum. (C)	Dugwell	PSF	Deep tubewell
Barisal			99	56	47	62	62	20
Chandpur			165	76	48	50	131	73
Chapai Nawabganj			226	53	45	229	38	141
Total sample area			**490 (26.6)**	**185 (10.0)**	**140 (7.6)**	**341 (18.5)**	**231 (12.5)**	**234 (12.7)**

Note: Figures in brackets are percentages (calculations based on 1,844 responses).
Some households did not mention a second preference.
Act. Alum. (H) and Act. Alum. (C) = activated alumina technology, household and community based, PSF = pond sand filter.

Table 7.5: Reasons for unwillingness to pay for arsenic mitigation technologies

District	Cannot afford it	Satisfied with current water quality	Others	Total respondents
Barisal	97 (32.7)	112 (37.7)	88 (29.6)	297
Chandpur	91 (47.9)	37 (19.5)	62 (32.6)	190
Chapai Nawabganj	68 (76.4)	20 (22.5)	1 (1.1)	89
Total sample area	**256 (44.4)**	**169 (29.3)**	**151 (26.2)**	**576**

Note: Figures in brackets are percentages.

7.4 Ranking of arsenic mitigation technologies

Respondents willing to pay for technologies were asked to list their first and second preference of technology keeping in mind the advantages and disadvantages of each technology, the convenience and risks, and the cost associated with the technologies.

The overwhelming preference was for deep tubewells, which were the first option for 72 percent[33] of the respondents and the second option for another 13 percent (see Table 7.4, Figure 7.3). The three-*kolshi* method was the second most preferred option, with about 16 percent of respondents ranking it first and another 27 percent ranking it second.

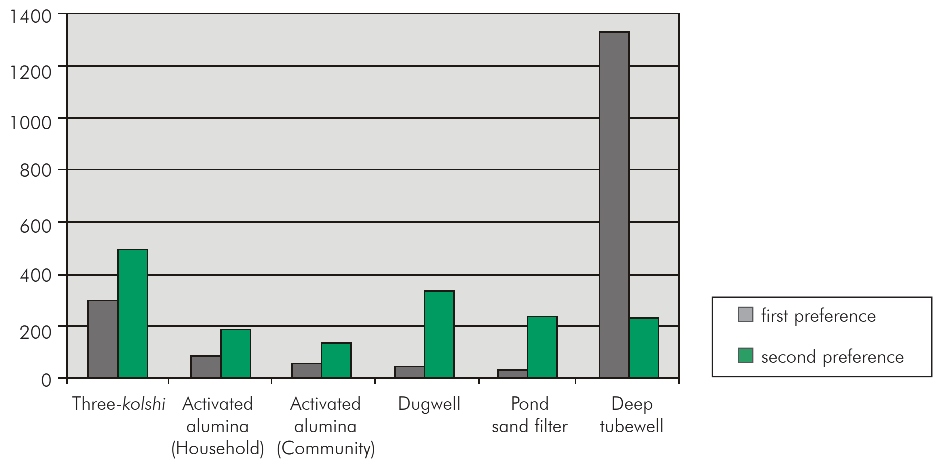
[33] In all, 1,844 respondents ranked the six technologies. Ten respondents who were willing to pay for the technologies did not rank them.

Table 7.6: Technology preferences of households currently using an arsenic mitigation technology or no technology

Households using	Preference for deep tubewell	Preference for three-*kolshi*	Preference for activated alumina technology	Number of households
Deep tubewell	484 (19)	45 (145)	21 (100)	891
Three-*kolshi* technology	9 (4)	3 (1)	0 (0)	20
Activated alumina technology	4 (0)	0 (0)	0 (2)	5
None of the above	838 (212)	243 (344)	128 (223)	1,515

Note: The first figure indicates the number of respondents who ranked the technology first while the figure in brackets indicates the number of respondents who ranked the technology second.

Fig. 7.3: Household ranking of the six selected arsenic mitigation technologies



Note: The figure shows the ranks given by the households to the six selected technologies (total number of households giving ranks is 1,854).

The next preferred option was the household-based activated alumina method, with about 5 percent of the respondents ranking it as the first preference and about 10 percent ranking it second. Community-based activated alumina was the next option of choice, with about 3 percent of the respondents ranking it first and about 8 percent ranking it second.[34]

Dugwells were given low preference in the ranking of technologies, and were ranked first by only

[34] It should be mentioned here that the technological advantages of activated alumina units over the three-*kolshi* method were explained in the interview. Respondents' possibly preferred the three-*kolshi* method over activated alumina units because the cost of three-*kolshi* technology was comparatively lower.

Respondents were given the following cost estimates for the selected technologies: three-*kolshi* method – initial cost Tk 300 and annual O&M cost Tk 150; activated alumina technology (household-based) – Tk 2,000 initially and annual O&M cost Tk 1,200; activated alumina technology (community-based), a more sturdy equipment to be shared by 7 families – Tk 3,000 initially and annual O&M cost Tk 2,000; deep tubewell shared by 40 families – initial cost Tk 1,250, negligible O&M cost.

Table 7.7: Comparison of technology preferences between poor and non-poor households

Technology	Poor households	Non-poor households
Three-*kolshi*	178 (283)	113 (207)
Activated alumina (household-based)	26 (82)	62 (103)
Activated alumina (community-based)	42 (75)	19 (65)
Dugwell	21 (184)	23 (157)
Pond sand filter	15 (119)	14 (112)
Deep tubewell	731 (151)	600 (83)

Note: The first figure indicates the number of respondents who ranked the technology first while the figure in brackets indicates the number of respondents who ranked the technology second.

2.4 percent of the respondents and second by about 19 percent. Pond sand filters, similarly, were ranked first by only 1.6 percent of the respondents and second by about 13 percent.

Deep tubewells were preferred both by households currently using them as well as by households not using any of these technologies (Table 7.6). Arsenic removal units were not the method of choice even among the respondents who had used or were using them. Only 3 of the 20 respondents who had used or were using the three-*kolshi* method opted for this method as a first choice and 1 respondent ranked it as a second choice. Similarly, none of the 5 respondents who had experience of using the activated alumina method ranked this technology as a first preference and 2 ranked it second. Thus, the survey results suggest that deep tubewells are preferred by households to the three-*kolshi* units or equipment based on activated alumina technology.

Comparative analysis of technology preferences of poor and non-poor households brings out that the preferences of the two categories were considerably similar (Table 7.7). For respondents belonging to both categories of households, the dominant preference was for deep tubewells, followed by three-*kolshi* method. One interesting, noticeable difference between the preferences of poor and non-poor households is that the respondents belonging to non-poor households had a stronger preference for the household based activated alumina technology than the community based activated alumina technology, while the converse was true for the respondents belonging to poor households.

7.5 Willingness to use subsidized arsenic mitigation technologies

Households reporting that they could not afford the technologies were asked whether they would be willing to use arsenic mitigation technologies if they were subsidized by 25 percent or 50 percent. As seen in Table 7.8 and Figures 7.4 and 7.5, about 46 percent (or about 5 percent of households surveyed in the sample area) were willing to pay for subsidized arsenic mitigation technologies — about 16 percent were willing to use the technologies if a capital subsidy of 25 percent was provided and another about 30 percent were willing to use the technologies if the subsidy was increased to 50 percent. Thus, in all about 81 percent of the respondents in the sample area would be willing to adopt mitigation technologies — 76 percent without any subsidy and 5 percent with a 50 percent capital subsidy.

Table 7.8: Willingness to use subsidized arsenic mitigation technologies

District	Households willing to use arsenic mitigation technologies if the capital cost is subsidized by		Households not willing to use the technologies even with subsidy
	25%	50%	
Barisal	24	29	44
Chandpur	12	28	51
Chapai Nawabganj	6	19	43
Total sample area	**42 (16.4)**	**76 (29.7)**	**138 (53.9)**

Note: Only respondents who said that they were not willing to use the technologies because they could not afford them were covered. Figures in brackets are percentages.

Figure 7.4: Capital subsidy, and willingness to pay for and use the selected technologies among households reporting that they cannot afford them

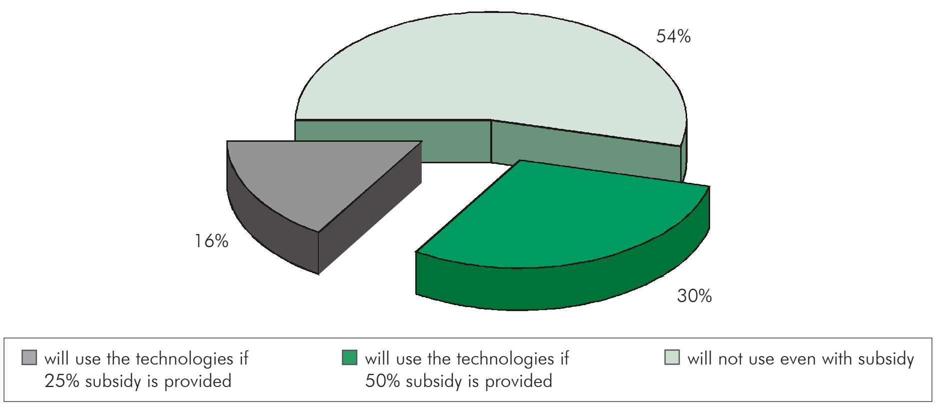
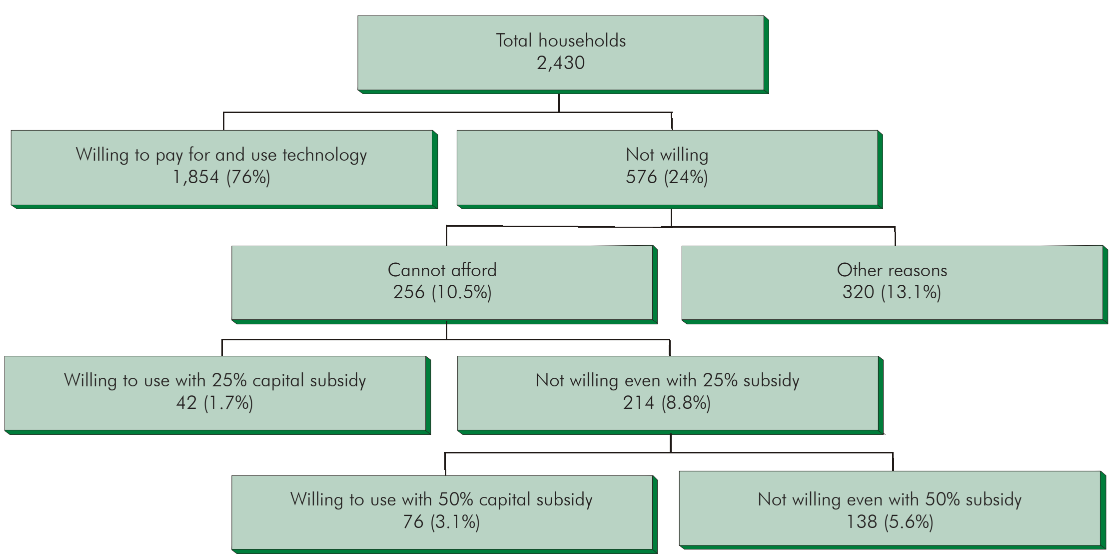


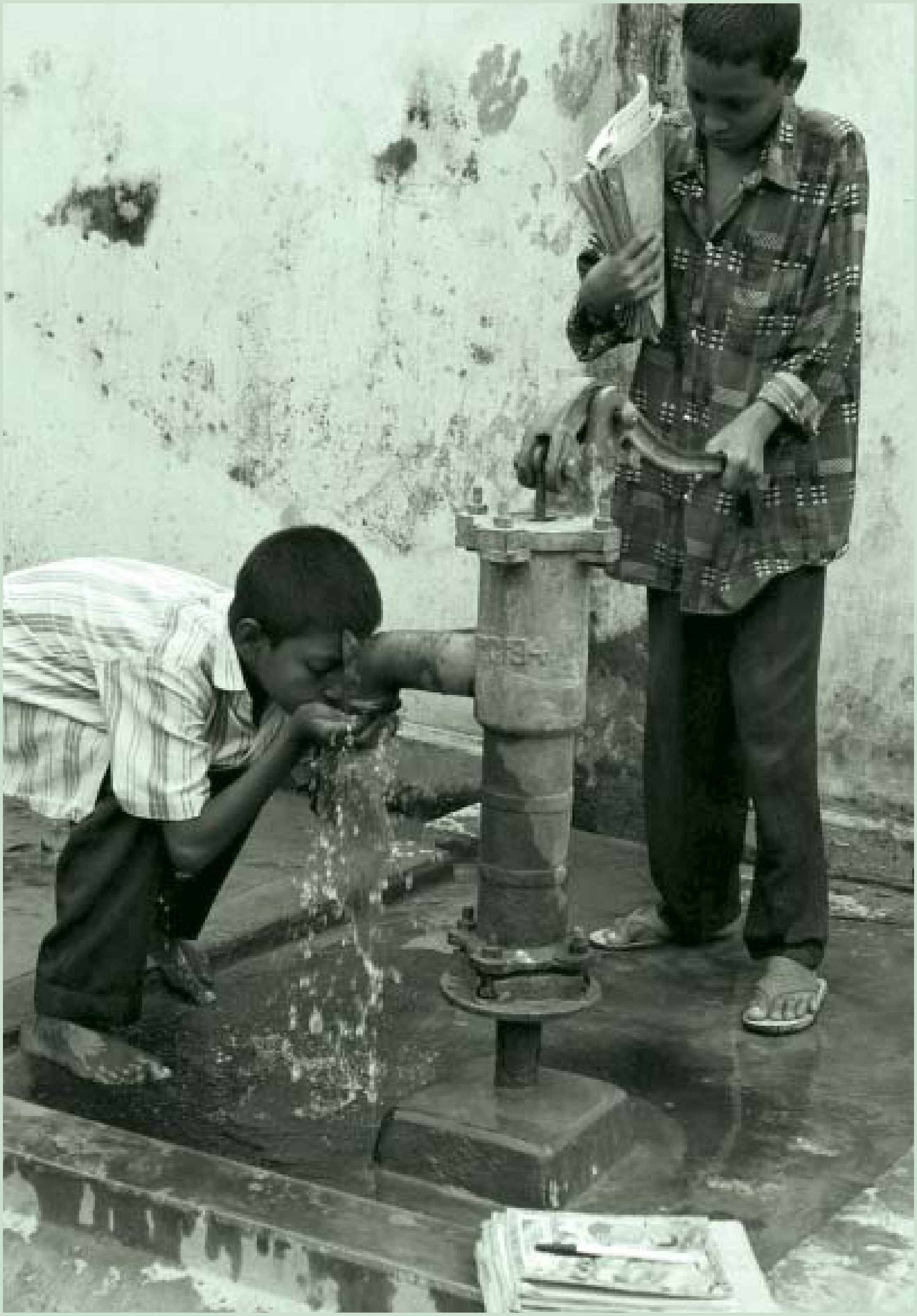
Figure 7.5: Respondents willing to pay for and use the six selected arsenic mitigation technologies



7.6 Summing up

Most respondents (76 percent) were willing to pay for and use one or more of the six arsenic mitigation technologies considered in this study. The overwhelming preference was for deep tubewells. After considering the risks and conveniences associated with each of the six technologies, as well as their capital and recurring cost, about 72 percent of the respondents ranked deep tubewells as their first preference. The three-*kolshi* method was relatively more preferred among the other technologies while dugwells and pond sand filters were relatively less preferred options.

About a quarter of the respondents were unwilling to pay for and use the technologies mainly because they could not afford the cost or they were satisfied with the quality of water they were accessing. Of the respondents who said that they could not afford arsenic mitigation technologies, half were willing to use these technologies if a capital subsidy of 50 percent was provided.



8 Are Households Willing to Pay for Piped Water Systems?

As mentioned in Chapter 2, piped water supply schemes can provide a long-term solution to the arsenic problem and are a major focus of this study. A significant advantage of these systems is the convenience they provide. While meeting the need of the household for arsenic-free water, they can also deliver water of the appropriate quality and in adequate quantity. However, a crucial question is: are rural households in Bangladesh willing to pay for piped water, and if so to what extent? These issues are addressed in this chapter.

The questionnaire was designed to compare the willingness of respondents to pay for piped water in the arsenic-affected areas and the arsenic-free areas and to assess the extent of their contribution. Details of the piped water scheme were first explained to the respondents. The scheme would be based on surface water where available, or a safe groundwater source, and supplied through a private connection or a public standpost. The quantity of water supplied would satisfy their needs for drinking, cooking, bathing, and washing, the timings of water supply would be reliable, and the quality of water supplied would be potable and free from arsenic and bacteriological contamination. The scheme would be implemented and managed by an agency of their choice.

Respondents were then asked whether they would opt for a piped water scheme, what they considered the advantages of piped water to be, and how much they would be willing to contribute towards the initial capital cost and O&M of the scheme. Households that were not able to contribute to the initial capital cost in cash were given the choice of contributing in terms of labor days. However, as most respondents did not agree to this option, the data on willingness to pay in terms of labor days was limited and has not been analyzed.

The methodology used has been discussed in Chapter 3. A contingent valuation methodology and an econometric model were used to assess the preferences of rural communities for piped water (standposts or domestic connections) and to derive estimates of average willingness to pay for these systems. The study also sought to estimate the value that respondents place on arsenic-free water out of the total value of piped water based on the contingent valuation approach. These estimates were validated against an alternate estimate arrived at based on the revealed preference approach.

Table 8.1: Perceived advantages of piped water systems

District	Perceived benefits of a piped water system*					
	No advantage	Clean water	Better for health	More convenient	Others	Total households
Sample area						
Barisal	27	432	248	479	1	807
Chandpur	29	487	437	361	21	778
Chapai Nawabganj	27	532	468	324	71	845
Total sample area	**83 (3.4)**	**1,451 (59.7)**	**1,153 (47.4)**	**1,164 (47.9)**	**93 (3.8)**	**2,430**
Control area						
Chapai Nawabganj	0	116	63	54	0	150
Commilla	14	140	76	56	0	150
Total control area	**14 (4.7)**	**256 (85.3)**	**139 (46.3)**	**110 (36.7)**	**0 (0.0)**	**300**

Note: Figures in brackets are percentages.
** Multiple responses were considered.*

Table 8.2: Would respondents vote in favor of a piped water scheme in the village?

District	Would the respondent vote for a piped water scheme		
	Yes	No	Don't know/ Not sure
Sample area			
Barisal	794	6	7
Chandpur	738	36	4
Chapai Nawabganj	837	1	7
Total sample area	**2,369 (97.5)**	**43 (1.8)**	**18 (0.7)**
Control area			
Chapai Nawabganj	150	0	0
Commilla	150	0	0
Total control area	**300 (100)**	**0 (0.0)**	**0 (0.0)**

Note: Figures in brackets are percentages.

8.1 Perceived advantages of a piped water supply system

A number of respondents in both the sample and control areas reported dissatisfaction with the quality of water currently being accessed and felt that piped water supply would provide significant advantages (Table 8.1). Respondents in the control area reported that amongst other problems, the water being used for cooking was turbid or had a foul smell (about 33 percent), and the water being used for purposes other than drinking and cooking was turbid (12 percent) (see Chapter 6). In the sample area, similarly, about 20 percent reported that the water being used for cooking was turbid or had a foul smell, while 16 percent mentioned similar problems with the water being used for purposes other than cooking and drinking. High iron content in the drinking water was another problem mentioned (12 percent in the sample area and 54 percent in the control area).

Roughly 60 percent of the respondents in the sample area felt that a piped system would provide clean water (referring to the physical properties of water, such as being free from excess iron), 48 percent felt that a piped system would be convenient, and 47 percent felt that piped water would be good for health. Similar responses on the advantages of piped water were obtained in the control area. About 85 percent said that a piped water system would provide clean water, 46 percent felt that it would be good for health, and 37 percent felt that it would be convenient.

A related question about the advantages of a domestic piped water connection was also asked. As expected, most of the respondents (over 70 percent) in both the sample and control areas considered convenience to be the main advantage.

To assess the extent of respondents' preferences for piped water supply, a hypothetical question was asked whether they would vote in favor of a piped water scheme if a poll was taken in their village on the issue. It was explained that respondents would be required to contribute 20-25 percent of the capital cost of the scheme and cover the entire O&M cost. The response indicated that an overwhelming majority (98 percent in the sample area and 100 percent in the control area) would vote in favor of a piped water scheme (Table 8.2).

8.2 Household willingness to pay for piped water

8.2.1 Value elicitation format: Closed-ended referendum and split sampling

For value elicitation, a closed-ended referendum coupled with split sampling was used in the study (for details of the methodology, see Chapter 3 and Annex B). The sample for the arsenic-affected area and the arsenic-free control area was divided into five sub-samples. In each of the sub-samples, a different charge was quoted for public standposts and domestic connections in each area. The values were based on the estimated cost of setting up and operating a piped water supply scheme in rural Bangladesh (see Box 8.1), assuming that beneficiary households would pay a minimum of 10 percent of the capital cost and the entire O&M cost. Since the cost of a scheme is likely to vary with the project design and local hydrogeological conditions, both the average cost and the likely range of variation in cost were considered when choosing the referendum values.

Five different levels of charges for public standposts and domestic connections were quoted during the interview in the five sub-samples in each area (see Annex B), and the respondents were asked to choose between a public standpost and a domestic connection. A third choice was to reject both options and to continue to depend on the present sources of water. The responses obtained with regard to the preference to pay for the O&M and capital cost for a standpost, a domestic connection, or neither, provided the basic data, which have been analyzed econometrically to estimate the willingness to pay for piped water supply (see Annex B).

The quoted monthly share of O&M cost for a public standpost ranged from Tk 10 per month in the first sub-sample to Tk 50 per month in the fifth sub-sample, while that for a domestic connection ranged from Tk 30 per month in the first sub-sample to Tk 100 per month in the fifth sub-sample (see Annex B).[35] The share of the initial capital cost quoted during the interview ranged from Tk 200 in the first sub-sample to Tk 1,000 in the fifth sub-sample for a public standpost, and Tk 500 to Tk 3,000 (first to fifth sub-sample) for a domestic connection.

As may be seen, the charges that were quoted for piped water varied significantly across the different sub-samples. While in the first sub-sample, the charges quoted were lower than the estimated O&M and capital cost of piped water supply, in the fifth

[35] The monthly charges for piped water quoted in the five sub-samples were Tk 10, 20, 30, 40 and 50 per month for a public standpost and Tk 30, 50,70, 90 and 100 for a domestic connection.

Box 8.1

Cost of piped water supply in rural Bangladesh

The estimated cost of setting up and operating a piped water system in the three areas covered in the study was based on the cost of four piped water supply projects in Bangladesh — the Bhashubihar project in Bogra (Rural Development Academy); the rural piped water supply project of the Watsan Partnership Project in Rajshahi; the rural water supply project in the Barind area (Barind Multipurpose Development Authority); and the BRAC (Bangladesh Rural Advancement Committee) project at Narayanganj. The DPHE was also consulted on the cost of establishing piped water systems in deep tubewell areas (see Annex C for details). The estimates are detailed below.

Estimated cost of piped water supply per household

Area/district	Public standpost/shared connection		Domestic connection	
	O&M cost (Tk/month)	Capital cost (Tk)	O&M cost (Tk/month)	Capital cost (Tk)
Low water table area (Chapai Nawabganj)	34	4,750	60	9,500
Shallow tubewell area (Chandpur)	34	4,750	60	9,500
Deep tubewell area (Barisal)	37	6,250	65	12,500
Average cost	35	5,250	62	10,500

The capital cost of setting up a transmission and distribution network for a piped water system in rural Bangladesh is less than some recent rural water supply projects in India due to the proximity of water sources and the dense settlement pattern in Bangladesh. However, as the coverage of electrification in rural Bangladesh is relatively low, the implementation of piped water supply systems in many villages would require an additional investment in non-grid power supply. This additional investment has been considered in the cost estimates reflected in the above figures.

sub-sample, the charges quoted were higher than the estimated cost. The charges quoted in the other sub-samples fell between the two.

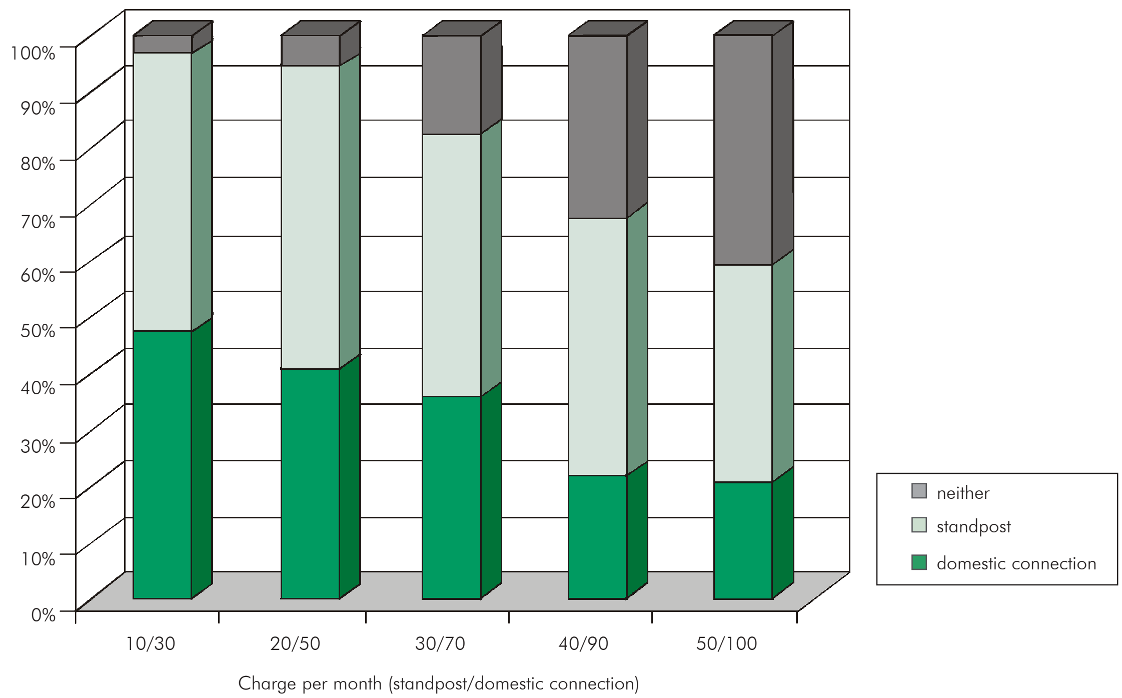
8.2.2 Piped water charges and demand for such systems

8.2.2.1 Sample area

The results of the survey for the sample area, based on a closed-ended referendum and split sampling, clearly reveal the inverse relationship between piped water charges and the demand for such systems (Figure 8.1). Fewer respondents opted for piped water in the sub-samples where higher charges were quoted. In the first sub-sample where the lowest prices were quoted, almost all the respondents (96 percent) said that they would opt for a piped water system. In contrast, in the fifth sub-sample, where the highest prices were quoted, only 57 percent of the households opted for piped water (less than half did not opt for piped water at the quoted charges).

At the middle range of charges (sub-sample 3), about 49 percent of the households opted for a standpost and about 31 percent opted for a domestic connection (see Figure 8.1). The other households (20 percent) said that they would not opt for a piped water supply at the charges quoted. The ratio of households opting for a domestic connection to those opting for a standpost was 1:1.5. Based on the three

Figure 8.1: Household choices regarding piped water supply: Sample area



mid-prices (sub-samples 2, 3 and 4), the corresponding ratio was 1:1.6.

8.2.2.2 Control area

The inverse relationship between piped water charges and the demand for such systems is also reflected in the survey results for the control area. In the first sub-sample where the lowest charges were quoted, 95 percent of the households opted for piped water. In the fifth sub-sample where the highest charges were quoted, only 55 percent of the households opted for piped water. These figures are similar to corresponding estimates for the sample area.

The survey results for the control area are similar to those for the sample area in respect of the ratio of households opting for a domestic connection to those opting for a standpost. At the middle level of charges (sub-sample 3), about 50 percent of the households in the control area opted for public standposts and about 37 percent opted for a domestic connection. The ratio of households opting for a domestic connection to those opting for a standpost was 1:1.4.

8.2.3 Analyzing the sample area data using a multinomial logit model

A multinomial logit model was applied to the survey data of the sample area to econometrically analyze household preferences for piped water supply and derive estimates of the willingness to pay for such a service (see Table 8.3) (for details see Annex B). Two levels of service were proposed and hence considered in the model — supply through a public standpost (shared) and a domestic piped water connection. The corresponding equations are included in Table 8.3.

Nine explanatory variables were used in the model for the arsenic-affected sample area, including the quoted charges for piped water supply, household income, and the socio-economic characteristics of the respondents. An index for the awareness and concern about the arsenic problem was also included as these would be important factors influencing

Table 8.3: Household preferences for piped water services in the sample area: Results of the multinomial logit model

No. of observations = 2,430

Explanatory variable	Public standpost		Domestic connection	
	Coefficient	t-ratio	Coefficient	t-ratio
Income (Tk '000)	0.1801	6.31*	0.2777	9.33*
Arsenic score	0.1533	1.67#	0.3462	3.58*
Charge for standposts	-0.0559	-14.10*		
Charge for domestic connections			-0.0359	-16.24*
Households that				
Consider piped water more convenient	0.7021	4.93*	0.8671	5.15*
Consider piped water good for health	0.5815	4.73*	0.8512	6.09*
Education (Class X and above)			0.7235	6.16*
Occupation of the household head				
Farmer	0.3999	3.12*	0.5063	2.98*
Service			0.7374	4.70*
Business	0.5563	3.29*	1.0255	5.09*
Constant	1.4416	5.96*	0.6859	2.34*
LR Chi^2 (16)	799.85			

Note: Arsenic score is an index reflecting awareness and concern of the arsenic problem.
** Statistically significant at 5 percent or higher level.*
 # Statistically significant at 10 percent level.

people's demand for piped water supply in the sample area. This is reflected by an arsenic score formulated through a principal component analysis applied to responses to nine arsenic-related questions (see Table 8.4).

The results of the multinomial logit model for the arsenic-affected areas indicate that the demand for piped water increases with income and declines with an increase in charges for a piped water supply (Table 8.3).[36] The results also show that the higher the awareness and concern for arsenic contamination (measured by an arsenic score), the greater the inclination to opt for a piped water system. Another inference that can be drawn from the results is that convenience and the health benefits of piped water are important considerations in household demand for piped water supply. The results also indicate that education (above Class X) raises the demand for a domestic piped water connection. Further, households where the head is a farmer, or in business or service, are relatively more inclined to opt for piped water supply than those where the head is an agricultural laborer or a manual worker.

8.2.4 Estimates of willingness to pay for piped water in the sample area

Based on the results of the survey, the mean willingness to pay for piped water in the sample area was estimated (see Table 8.5). Estimates for the amount households were willing to pay as an initial contribution to capital cost and O&M per month for both public standposts and domestic connections were made.

The mean willingness to pay among different categories (poor and non-poor households, or for each district) was derived using the estimated

[36] These results (and the later finding that the mean willingness to pay for a domestic connection is more than for a public standpost) are consistent with economic theory, suggesting that the responses obtained to the contingent valuation question meet the test of construct validity (see Chapter 3).

Table 8.4: Variables used to develop the index of arsenic awareness and concern

	Variable	Value*
1	Is any member of your family affected by arsenicosis?	1 = Yes, 0 = No
2	Are any of your neighbors affected by arsenicosis?	1 = Yes, 0 = No
3	Is anyone in your village affected by arsenicosis?	1 = Yes, 0 = No
4	Do you know anyone in the neighboring village affected by arsenicosis?	1 = Yes, 0 = No
5	Do you know that it takes a number of years before arsenic poisoning manifests itself, so a person may continue to use arsenic-contaminated water for many years without being aware of the arsenic poisoning taking place?	1 = Yes, I know, 0 = No, I don't know
6	Do you know that the prolonged use of arsenic contaminated water for drinking and cooking may cause gangrene and cancer, and may even lead to death?	0 = I knew that consumption of arsenic contaminated water can cause health problems, but I did not know that it can cause cancer 0 = I find it hard to believe that consumption of tubewell water can lead to cancer 0 = I am not convinced that arsenic contamination can cause cancer
7	Considering the health effects of arsenic and the related treatment cost, do you consider arsenic contamination of tubewell water a serious threat to your family's health?	1 = Yes, 0 = No, 0 = I don't know
8	Are you currently facing problems with the quality of drinking water due to arsenic contamination?	1 = Yes, 0 = No
9	In the last three years have you changed your drinking water source due to arsenic contamination?	1 = Yes, 0 = No

Note: Principal component analysis has been applied to construct the index and compute a score based on factor loadings.
** Re-coding has been done so that 0 indicates 'not aware' or 'not concerned'.*

coefficients from the multinomial logit model (Table 8.3) and the average values of the explanatory variables computed for each category from the survey data (for details of the methodology, see Annex B).

In the sample area, the estimated mean willingness to pay for water supplied through a public standpost was Tk 51 per month for O&M and Tk 960 as initial capital cost. For a domestic connection, willingness to pay was Tk 87 per month for O&M and Tk 1,787 as initial capital cost. Estimates for Chandpur were slightly higher than those for Chapai Nawabganj and Barisal possibly because of the relatively higher average income level and the greater concern for and awareness of arsenic contamination in this area.

Among poor households (monthly household income less than Tk 3,600), the estimated mean willingness to pay for a public standpost was Tk 44 per month for O&M in addition to an initial payment of Tk 838 towards the capital cost. For a domestic connection, these households were willing to pay Tk 68 per month for O&M and an initial payment of Tk 1,401. As would be expected, the estimated average willingness to pay among non-poor

Table 8.5: Estimated mean willingness to pay for piped water in the sample area

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital Cost (Tk)	O&M (Tk/month)	Capital cost (Tk)
District				
Barisal	49	927	83	1,716
Chandpur	55	1,043	99	2,038
Chapai Nawabganj	48	913	79	1,625
All	**51**	**960**	**87**	**1,787**
Poor	44	838	68	1,401
Non-poor	59	1,119	112	2,318
Willingness to pay as a percentage of income (%)*				
District				
Barisal	1.1	1.7	1.9	3.2
Chandpur	1.0	1.5	1.8	3.0
Chapai Nawabganj	1.3	2.0	2.1	3.6
All	**1.1**	**1.7**	**1.9**	**3.2**
Poor	1.9	3.0	2.9	5.0
Non-poor	0.8	1.2	1.5	2.6

** The ratio in respect of contribution to capital cost has been computed based on annual income figures. Capital cost is a one-time payment.*

households was significantly higher (Tk 59 per month for O&M and Tk 1,119 as initial capital cost for a public standpost, and Tk 112 per month for O&M and Tk 2,318 as initial capital cost for a domestic connection).

With regard to standposts, households were, on an average, willing to spend 1.1 percent of their monthly income on O&M and 1.7 percent of their annual income as the initial capital cost (Table 8.5). Poor households were willing to spend 1.9 percent of their monthly income on O&M and, on an average, were willing to pay 3.0 percent of their annual income as the initial capital cost.

Households were willing to spend about 1.9 percent of their monthly income as O&M charges for domestic connections and 3.2 percent of their annual income as the initial capital cost. Poor households were willing to spend 2.9 percent of their monthly income on O&M and about 5 percent of their annual income on initial capital cost.

On comparing the willingness to pay with actual cost, it is seen that the mean willingness to pay more than covers the actual O&M cost of a piped water supply scheme (estimates based on cost information of on-going schemes in Bangladesh) (Table 8.6). Households were willing to pay, on an average 46 percent more than the actual cost of O&M for standposts and 40 percent more for a domestic connection. Among poor households, the mean willingness to pay for standposts exceeded the O&M cost by more than 26 percent while the mean willingness to pay for a domestic connection exceeded the actual O&M cost by 10 percent.

The findings reveal that both poor and non-poor rural households were willing to pay more than 10 percent of the actual capital cost for a piped water scheme, which is often the stipulated share of the capital cost to be borne by households in rural piped water supply projects in developing countries (Table 8.6). The mean willingness to pay for all

Table 8.6: Average household willingness to pay as a percentage of actual cost in the sample area (percent)

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital cost (Tk)	O&M (Tk/month)	Capital cost (Tk)
District				
Barisal	132	15	128	14
Chandpur	162	22	165	21
Chapai Nawabganj	141	19	132	17
All	**146**	**18**	**140**	**17**
Poor	126	16	110	13
Non-poor	169	21	181	22

Note: The cost estimates are based on figures listed in Box 8.1.
Capital cost is a one-time payment.

households was 18 percent of the capital cost for a standpost and 17 percent of the capital cost for a domestic connection. Non-poor households were willing to pay 21 percent of the capital cost for a standpost and 22 percent of the capital cost for a domestic connection. Poor households were willing to contribute, on an average, 16 percent of the capital cost of a standpost and 13 percent of the capital cost of a domestic connection.

Information gathered on the willingness to pay in the village level survey support the findings of the household survey. District-wise information from village informers indicates that in Chandpur most households were willing to pay Tk 50-75 per month and contribute Tk 2,000-3,000 towards the capital cost of piped water supply. In Barisal, willingness to pay for O&M was Tk 30-50 per month and Tk 1,000-2,000 for the capital cost. In Chapai Nawabganj, where household income was lower, a relatively lower willingness to pay for piped water was reflected in the information collected at the village level.

8.2.5 Estimates for the control area based on the multinomial logit model

As for the sample area, a multinomial logit model was applied to the survey data of the arsenic-free control area to analyze household preferences for piped water supply and to derive estimates of the willingness to pay for such a service (Table 8.7). The results of the model were qualitatively similar to those obtained in the sample area (Table 8.3). The level of income and the cost of the service were found to be key factors determining the choice between a standpost and a domestic connection, or rejecting both. Convenience was an important consideration when opting for a piped water connection. Education above Class X appeared to increase the demand for a domestic piped water connection. Occupation of the household head was also important in determining the demand for piped water. Households where the head was a farmer or in business or service were more inclined to opt for a piped water connection.

Some differences would be noticed between the models for the sample area and the control area. The model for the sample area includes an arsenic score as an explanatory variable. Since concern for arsenic would not be an important factor influencing the demand for piped water in the arsenic-free control area, this variable was not included in the model for the control area. The dummy variable representing household perception that piped water is good for health was initially included in the model for the

Table 8.7: Household preferences for piped water services in the control area: Results of the multinomial logit model

Number of observations = 300

Explanatory variable	Public standpost		Domestic connection	
	Coefficient	t-ratio	Coefficient	t-ratio
Income (Tk '000)	0.2629	2.41*	0.4639	4.19*
Charge for standposts	-0.0883	-6.06*		
Charge for domestic connections			-0.0511	-6.46*
Households that consider piped water more convenient	1.5285	3.62*	1.5581	3.21*
Education (Class X and above)			1.4678	3.43*
Problem of excessive iron in the water	0.3523	0.95	0.4799	1.13
Occupation of the household head				
Farmer	1.6313	3.49*	2.2757	4.15*
Service	1.6149	1.99*	2.0509	2.36*
Business	1.6762	2.77*	2.1085	3.01*
Constant	1.2401	1.90	0.2338	0.29
LR Chi^2 (15)	170.78			

**Statistically significant at 5 percent or higher level.*

Table 8.8: Estimated mean willingness to pay in the control area

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital cost (Tk)	O&M (Tk/month)	Capital cost (Tk)
District				
Chapai Nawabganj	42	859	76	1,491
Commilla	50	1,014	105	2,059
All	**46**	**937**	**91**	**1,775**
Poor	39	785	67	1,310
Non-poor	56	1,135	122	2,385
Willingness to pay as a percentage of income (%)*				
District				
Chapai Nawabganj	1.5	2.6	2.8	4.5
Commilla	0.8	1.3	1.6	2.7
All	**1.0**	**1.7**	**2.0**	**3.2**
Poor	1.7	2.8	2.9	4.7
Non-poor	0.7	1.3	1.6	2.6

** The ratio in respect of contribution to capital cost has been computed based on annual income figures. Capital cost is a one-time payment.*

control area, but was later dropped because the estimated coefficient was found to be statistically insignificant. It appears that the benefits to health of piped water were a more important consideration underlying the demand for piped water in the sample area than in the control area.

Another difference between the models for the sample and control areas is that the latter model includes a dummy variable representing the problem of excessive iron in the water. Although the coefficient of this variable was not statistically significant, it was retained in the equation because a number of respondents in the area (more than half) had reported this as a problem during the survey. The results of the model suggest that households facing this problem were more likely to opt for piped water than households that did not face such a problem.

8.2.6 Estimates of willingness to pay for piped water in the control area

Estimates of the mean willingness to pay in the control area (based on the multinomial logit model) are presented in Table 8.8. On an average, the mean willingness to pay for all households for a standpost was Tk 46 per month for O&M and Tk 937 as initial payment for capital cost. For a domestic connection, the mean willingness to pay was Tk 91 per month for O&M and Tk 1,775 as initial capital cost.

The mean willingness to pay was higher in Commilla than in Chapai Nawabganj perhaps because the *thana* surveyed in Commilla was better developed than the *thana* covered in Chapai Nawabganj, which is reflected in the relatively higher levels of income in Commilla.

In the control area, the estimated mean willingness to pay for a public standpost among poor households was Tk 39 per month plus an initial payment of Tk 785. For a domestic connection, these households were prepared to pay Tk 67 per month, plus an initial payment of Tk 1,310. The estimated willingness to pay of non-poor households was significantly higher. On an average, non-poor households were prepared to pay Tk 56 per month for O&M and Tk 1,135 as initial capital cost for a standpost, and Tk 122 per month as O&M and Tk 2,385 as initial capital cost for a domestic piped water connection.

The estimated mean willingness to pay was only a small percentage of household income, which is similar to the estimates for the sample area. The mean willingness to pay for O&M for all households for a standpost was about 1 percent of monthly income and about 2 percent for a domestic connection. Poor households were willing to pay 1.7 percent of their monthly income as O&M charges for a standpost and 2.9 percent of their monthly income as O&M charges for a domestic connection. The non-poor were willing to pay 0.7 percent and 1.6 percent of their monthly income as O&M charges for a standpost and domestic connection, respectively.

The contribution towards initial capital cost as a percentage of annual income was about 1.7 percent for a standpost and 3.2 percent for a domestic connection. Poor households were willing to pay 2.8 percent of their annual income as the initial cost of a standpost and nearly 5 percent of their annual income as the initial capital cost of a domestic piped water connection. The non-poor were willing to pay 1.3 percent of their annual income as initial cost of a standpost and 2.6 percent of their annual income as initial capital cost of a domestic connection.

A comparison of estimated mean willingness to pay with the actual cost of supply (Table 8.9) reveals a similar picture as in the sample area. The estimated mean willingness to pay for O&M exceeded the actual cost by 35 percent for a standpost and 52 percent for a domestic connection.

The mean willingness to pay for O&M of standposts among non-poor households exceeded the actual cost by 65 percent. For a domestic connection, the corresponding proportion was 103 percent. For poor households, the willingness to pay was relatively lower although their average willingness to pay for O&M exceeded the actual cost both for standposts and domestic connections.

Table 8.9: Average household willingness to pay as a percentage of actual cost in the control area (percent)

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital cost (Tk)	O&M (Tk/month)	Capital cost (Tk)
District				
Chapai Nawabganj	124	18	127	16
Commilla	147	21	175	22
All	**135**	**20**	**152**	**19**
Poor	115	17	112	14
Non-poor	165	24	203	25

Note: Cost estimates are listed in Box 8.1.
Capital cost is a one-time payment.
As Commilla district is in a shallow tubewell area, the estimates for Chandpur (shown in Box 8.1) were used. The capital cost of piped water supply for the aggregate control area was estimated as Tk 9,500 per family for a domestic connection and Tk 4,750 per family for a public standpost.

With regard to the capital cost, the estimated mean willingness to pay for all households was 20 percent of the capital cost of a standpost and 19 percent of the capital cost of a domestic connection. Poor households were also willing to contribute significantly to the capital cost of piped water supply and were willing to pay, on an average, 17 percent of the initial capital cost for a standpost and 14 percent of the initial cost for a domestic connection. Non-poor households were willing to contribute 24 percent of the capital cost for a standpost and 25 percent of the capital cost for a domestic connection.

8.3 Willingness to pay for piped water as a percentage of income: A review of studies in developing countries

Studies of developing countries have shown that households would be willing to pay 0.2 percent to more than 4 percent of their income to use an improved water source (see Whittington and Swarna, 1994; World Bank Water Demand Research Team, 1993). In most cases, the ratio is between 1 to 2 percent. In Parana state in southern Brazil, for instance, households were willing to pay about 2 percent of their income for a private connection; however, they were not willing to pay for a public standpost (World Bank Water Demand Research Team, 1993: 51). In southern Haiti, households were willing to pay approximately 1 percent of their income for a public standpost and about 2 percent for a private connection (Whittington et al., 1990). In sweet-water zones of the Punjab, in Pakistan, almost every household has a handpump in the house or compound; in these areas, households were willing to pay about 1 percent of their income for a domestic piped water connection (Altaf et al., 1993).

A study of rural piped water supply in Kerala, India in 1988 shows that households were willing to pay an average monthly tariff of Rs 5.5 for a domestic connection in areas that did not have access to piped water services at the time and an average of Rs 267 as a connection charge (Singh et al., 1993). In areas with piped water schemes, households without a water connection were willing to pay a monthly tariff of Rs 8.7-9.7 depending on the quality of service, and Rs 355 as a connection charge. Households with a piped water connection were willing to pay a monthly tariff of Rs 25 for improved water services. Based on the average annual per capita income reported in the study (assuming an average family size of six), the percentage of monthly income that households would be willing to pay as monthly tariff was in the range of 0.4-2 percent.[37]

[37] This is one of few studies where contingent valuation (in 1988) was followed by a behavioral study (in 1991) when water supply projects were implemented (Griffin et al., 1995). The behavior of households was found to be consistent with the findings of the contingent valuation survey, thereby validating the willingness to pay estimates based on this methodology.

Clearly, the estimates of willingness to pay for piped water as a percentage of income for rural Bangladesh obtained in this study broadly correspond with the estimates obtained in a number of earlier studies, which indirectly corroborates the reliability of these estimates.[38]

8.4 Value of arsenic-free water

Piped water is a composite good whose value is made up of a number of elements including quality, convenience, and saving of time. In arsenic-affected areas, the estimated value of piped water would have an element related to its being arsenic-free. A challenging methodological issue is how to extract this element from the total value of piped water.

Two methods, contingent valuation and revealed preference, were used in the Bangladesh study to estimate the value of water being arsenic-free. The estimates obtained by the contingent valuation method and the revealed preference method are presented in the following sections.

8.4.1 Estimations based on the contingent valuation approach

To obtain estimates of arsenic-free water by the contingent valuation method, the mean willingness to pay for piped water was first estimated among households in the arsenic-affected areas that ranked relatively high (above the median) in terms of the arsenic score which reflect awareness and concern of the arsenic problem (see Table 8.10, Row A). This estimate was then compared with the mean willingness to pay for piped water in the arsenic-free control area (Row C). The difference was arrived at to estimate the willingness to pay for arsenic-free water (Row D).

The willingness to pay for O&M and capital cost was aggregated to obtain the total amount a household would be willing to pay a month. The monthly payment equivalent to the one-time payment of capital cost was worked out based on the interest cost (the amount a household would pay per month if they borrowed money to pay the initial capital cost; and in case they paid out of their savings, the amount of interest they would lose per month). Assuming an interest rate of 12 percent per annum,[39] one percent of the capital cost payment was added to O&M cost payment to calculate the total amount households would be willing to pay. Computed in this manner, the difference between Row A and Row C would be Tk 9 a month for a standpost and Tk 11 a month for a domestic connection, which would be the estimated value of arsenic-free water.

The multinomial logit model for the arsenic-affected area was used to obtain an alternate estimate of the value of arsenic-free water obtained by the contingent valuation method (see Table 8.3). All the arsenic-related variables included in the index were set at zero (Table 8.4) and other variables were set at the sample mean to arrive at an estimation of willingness to pay for piped water among households with no awareness or concern for the arsenic problem (Table 8.10, Row B). The mean willingness to pay arrived at was then compared with the mean willingness to pay for piped water among households that ranked relatively high on the arsenic score.

The estimate of the value of arsenic-free water, when standposts and domestic connections were considered separately, was Tk 6-9 per month for a public standpost and Tk 11-23 per month for a domestic connection (Table 8.10, Row D). The arsenic-free component was calculated to be 9-14 percent of the value of piped water in arsenic-affected areas in the case of standposts, and 9-19 percent in the case of a domestic connection (Row E).

To arrive at an estimate of arsenic-free water when the two options for piped water supply are considered

[38] Jiwanji (2000) has reviewed contingent valuation studies on the demand for improved water supply in developing countries. In 11 out of 15 studies, households were willing to pay 0.5-2.5 percent of their income per month for piped water.
[39] During 2001-02, the interest rate on deposits for two years or more with major banks in Bangladesh was 8-9 percent per annum. The agricultural lending rates ranged from 12 to 16 percent per annum. Therefore, the midpoint of these interest rates, that is, 12 percent, was used for the calculations.

Table 8.10: Willingness to pay for the arsenic-free component in piped water

	Public standpost			Domestic connection		
	O&M (Tk/month)	Capital cost (Tk)	Total payment (Tk/month)	O&M (Tk/month)	Capital cost (Tk)	Total payment (Tk/month)
(A) Sample area: Mean willingness to pay for households with an arsenic score above the median	54	1,024	64.2	99	2,041	119.4
(B) Sample area: Mean willingness to pay estimated after setting arsenic-related variables at zero	49	926	58.3	80	1,660	96.6
(C) Control area: Mean willingness to pay	46	937	55.4	91	1,775	108.7
(D) Mean willingness to pay for arsenic-free water (Tk per month)			6-9			11-23
(E) Arsenic-free element extracted from the value of piped water			9-14%			9-19%

Note: Mean willingness to pay for arsenic-free water in Row D was calculated as the difference between Rows A and B, and similarly the difference between Rows A and C. The difference was taken after combining the mean willingness to pay for capital cost with the mean willingness to pay for O&M. By adding 1 percent of the former to the latter, an estimate was made of the total amount households were willing to pay per month. The figures in Row E were obtained by dividing the estimated mean willingness to pay for arsenic-free water by the value of piped water indicated in Row A.

together, the willingness to pay for a standpost and a domestic connection were combined using weightages of 0.6 and 0.4 (based on the preferences indicated by households in the survey). The difference in the mean willingness to pay was Tk 13 a month when Rows A and B were compared (the weighted average of 58.3 and 96.6 was subtracted from the weighted average of 64.2 and 119.4), and Tk 10 per month when Rows A and C were compared (the weighted average of 55.4 and 108.7 was subtracted from the weighted average of 64.2 and 119.4). Based on these figures, willingness to pay for arsenic-free water would be in the range of Tk 10-13 a month.

As a proportion of income, the willingness to pay for arsenic-free water was low, ranging from 0.2 percent to 0.3 percent. This probably reflects the long latency period of arsenicosis and the high personal discount rate for the future among rural households (Poulos and Whittington, 2000). Another possible reason for the low value of arsenic-free water is the perception of risk similar to those detected in most risk studies, that is "it will not happen to me or my family members".

8.4.2 Estimates based on the revealed preference approach

To validate the estimates of the value of arsenic-free water based on the contingent valuation approach discussed earlier, alternate estimates were made based on the revealed preference approach. Using the revealed preference approach, four components were valued and aggregated to estimate the value of arsenic-free water:

- The value of the extra time being spent on collecting drinking water by households that had shifted their drinking water source as a result of arsenic contamination.
- The value of time spent and fuel used to boil water among households that had shifted from tubewells to sources such as tanks and ponds, and were boiling water to remove bacteriological contamination.
- The cost of interest on investments made in new tubewells, or re-sinking existing tubewells deeper, among households that had made such an investment because the earlier source of drinking water was arsenic-contaminated.

Table 8.11: Estimated value of arsenic-free water according to the revealed preference approach

	Indicator	Value
1.	Total households surveyed in the sample area	2,430
2.	Number of households that changed their drinking water source due to arsenic contamination	502
3.	Total value of extra time spent collecting water by households that changed their drinking water source due to arsenic contamination (Tk per month)	17,480
4.	Number of households that have shifted to other sources such as ponds/tanks and are boiling water	49
5.	Total value of time and fuel cost for boiling water among households that have shifted to tanks/ponds (Tk/month)	11,123
6.	Number of households that have installed a new tubewell in the last five years due to arsenic contamination	75
7.	Monthly interest cost of investment (at the rate of 12% per annum) (Tk/month)	1,875
8.	Total sum of cost (3+5+7) (Tk/month)	30,478
9.	Cost per household per month (8/1) (Tk/month)	12.5
10.	Excluding the 554 households whose tubewells have been found safe (Tk/month)	16.2

Note: See Annex D for details of computation.

- The cost associated with arsenic reduction units among households that had been using such technology.

The estimated values are reflected in Table 8.11 (for detailed computations, see Annex D). One component (the cost associated with arsenic reduction units) was not estimated because households probably did not incur much actual expenditure operating and maintaining the equipment.

The sum of cost incurred by households to obtain arsenic-free water (arrived at by adding the cost of extra time spent collecting drinking water, the cost of time spent and expenditure incurred on fuel to boil tank/pond water and cost of interest on investment in new tubewells) was Tk 30,478 per month. The total cost was then divided by the total number of households surveyed in the sample area to arrive at the per household cost, which was Tk 12.5 per month.[40] It may be appropriate to exclude from the calculations households reporting that the tubewell had been found to be safe after testing, as they would not be required to incur any additional expenditure. If these households were excluded (554 households, see Table 6.17), the average cost would be Tk 16.2 per household per month.

The estimates of the value of arsenic-free water obtained by the revealed preference approach are broadly in agreement with the estimates arrived at using the contingent valuation approach, thereby validating the estimates of the latter.

[40] The total cost was divided by the total number of households in the sample area to be consistent with the estimate based on the contingent valuation approach.

8.5 Summing up

The estimates of willingness to pay for piped water indicate a strong preference for such systems both in the arsenic-affected and arsenic-free areas. The results suggest that rural households were willing to pay for piped water particularly because of the convenience it provides. On an average, the estimated mean willingness to pay of all households exceeded the actual O&M cost of supplying piped water in both arsenic-affected and arsenic-free areas. In the arsenic-affected areas, for instance, the mean willingness to pay for the O&M cost of a public standpost was Tk 51 per month, 46 percent higher than the actual cost, and the mean willingness to pay for a domestic connection was Tk 87 per month, 40 per cent higher than the actual cost. Even poor households were willing to pay more than the actual O&M cost of piped water supply, both for public standposts and domestic connections (26 percent more than the actual O&M cost for a standpost and 10 more than the actual O&M cost of a domestic connection).

In rural piped water supply projects in India, beneficiaries are often required to contribute 10 percent to the capital cost of the project. This is also roughly the stipulated share of beneficiary contribution in a number of rural water supply projects in other developing countries. The results of this study indicate that rural households in Bangladesh would be willing to cover the capital cost to this extent and even more.

In the study, an estimate was made of the value of making water arsenic-free out of the total value of piped water. The estimate was in the range of Tk 10-13 a month, using the contingent valuation approach. An alternate value of arsenic-free water arrived at using the revealed preference method was found to be in the same range as the estimates obtained by the contingent valuation approach, thus validating the estimates of the latter.

The estimated value of arsenic-free water was low in comparison to the average income of rural households (0.2-0.3 percent). The low willingness to pay for arsenic-free water among rural households probably reflects the long latency period of arsenicosis and the high personal discount rate for the future. Other reasons include low awareness of the serious health effects of arsenic contamination and low risk perceptions among rural households.

9 Piped Water Systems or Arsenic Mitigation Technologies — What do Households Prefer?

The survey data presented in the previous chapter clearly reflect a strong preference for piped water supply. However, findings also show that majority of households in the arsenic-affected areas are willing to pay for and use arsenic mitigation technologies. This chapter explores household preferences between piped water supply and arsenic mitigation technologies, and the reasons for their choice. As arsenic mitigation technologies are not of interest to households in the arsenic-free control area, households in the control area were not asked about these technologies and hence were not required to make a choice between piped water and the arsenic mitigation technologies.

9.1 Choice between piped water supply and arsenic mitigation technologies

Respondents were asked to state their preference between piped water supply and their most preferred arsenic mitigation technology (out of the six included in the study), and the reasons for their choice. However, because of the asymmetry between the charges quoted in the survey for piped water and arsenic mitigation technologies,[41] households were asked to make a choice between the two options under two conditions: with no capital subsidy for arsenic mitigation technologies, and assuming that there was an 80 percent capital subsidy on the technologies. Such questions are useful to study the sensitivity of respondents to the level of subsidy on arsenic mitigation technologies.

Most respondents (89 percent) showed a preference for piped water supply over arsenic mitigation technologies (taking into account aspects of cost, convenience, and other issues) (Table 9.1, Figure 9.1).[42] Even with the provision of 80 percent

[41] While it was assumed that households would pay only a part (about 10-20 percent or one-fifth) of the initial capital cost of piped water systems, the charges for arsenic mitigation technologies did not have any built-in subsidy on capital cost.

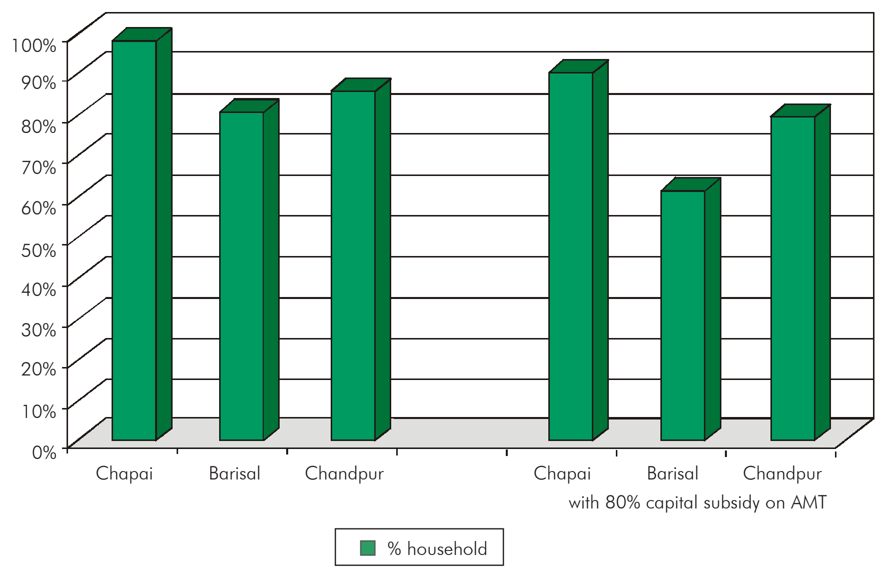
[42] Table 9.1 and Figure 9.1 are based on data for 2,280 households out of a total of 2,430 households covered in the sample area. Respondents who did not want to contribute to the capital cost of piped water schemes (150 respondents) were excluded from the analysis.

Table 9.1: Household choice between piped water supply and arsenic mitigation technologies

District	Household preference			Household preference if 80 percent capital subsidy is provided for arsenic mitigation technologies		
	Piped water supply	Arsenic mitigation technology	Not specified/ indifferent	Piped water supply	Arsenic mitigation technology	Not specified/ indifferent
Barisal	561 (80.9)	130 (18.8)	2 (0.3)	424 (61.2)	265 (38.2)	4 (0.6)
Chandpur	637 (85.7)	101 (13.6)	5 (0.7)	586 (78.9)	152 (20.4)	5 (0.7)
Chapai Nawabganj	825 (97.7)	16 (1.9)	3 (0.4)	761 (90.2)	76 (9.0)	7 (0.8)
Total sample area	**2,023 (88.7)**	**247 (10.8)**	**10 (0.4)**	**1,771 (77.7)**	**493 (21.6)**	**16 (0.7)**

Note: Figures in brackets are percentages.
The first column indicates household choice with a capital subsidy on piped water.

Figure 9.1: Household preference for piped water over arsenic mitigation technologies (%)



capital subsidy on arsenic mitigation technologies, the proportion of respondents preferring piped water supply remained high (about 78 percent).

More households in Chapai Nawabganj (98 percent) than in Barisal and Chandpur (81 and 86 percent, respectively) preferred piped water supply to arsenic mitigation technologies (Table 9.1). In Barisal, about 19 percent of the respondents preferred arsenic mitigation technologies to piped water supply without any capital subsidy on arsenic mitigation technologies but the capital cost of piped water subsidized to an extent. With a provision for 80 percent capital subsidy on arsenic mitigation technologies, the relevant proportion rises to 38 percent (Table 9.1), that is, an increase of 19 percentage points. In Chandpur and Chapai Nawabganj, in comparison, fewer households opted to shift to subsidized arsenic mitigation technologies. The proportion of households preferring arsenic mitigation technologies to piped water increased by about 7 percentage points in both districts with the provision of 80 percent capital subsidy.

About 69 percent of the 2,023 respondents who chose piped water over arsenic mitigation technologies mentioned convenience as the main reason or one of the reasons for choosing this option. Over half (51 percent) felt that a piped water system would provide safe water free from arsenic as well as bacteriological contamination, and about 6 percent felt that a piped water system would supply enough water to meet their requirements. About 18 percent of the respondents said that they had chosen piped water over their most preferred arsenic mitigation technology because of the cost in addition to other advantages of piped water.

As deep tubewells were the most preferred arsenic mitigation technology in majority of cases, the comparison shown in Table 9.1 is essentially between piped water and deep tubewells. However, piped water was the preferred option even among households that had chosen three-*kolshi* or activated alumina units as their most preferred arsenic mitigation technology (Table 9.3).

The survey explored whether households that had used an arsenic mitigation technology earlier would have the same preferences as those that had no experience of using the technology. Similarly, the preferences of households that had previously used arsenic reduction units and those that had used deep tubewells were also analyzed.

Table 9.2: Reasons for preferring piped water supply to arsenic mitigation technologies

Reason	Number of households	Percent
Convenience	1,390	68.7
Piped water is free from arsenic and bacteriological contamination	1,043	51.6
Cost considerations	365	18.0
Sufficient water will be available	122	6.0
Other reasons	13	0.6
Total number of households	**2,023**	

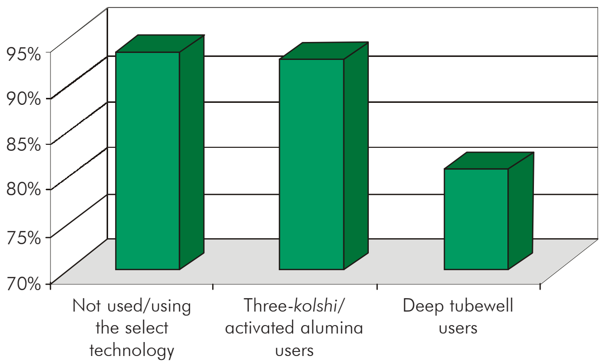
Note: Multiple responses were considered.

Table 9.3: Choice between piped water supply and arsenic mitigation technologies: A comparison of households grouped according to their most preferred arsenic mitigation technology

Most preferred technology	Number of respondents	Preferred option between piped water supply and selected arsenic mitigation technology		
		Piped water	AMT	Not specified/ Indifferent
Three-*kolshi*	289	279	8	2
Activated alumina (H)	94	91	3	0
Activated alumina (C)	61	61	0	0
Dugwell	45	43	2	0
Pond sand filter	31	28	3	0
Deep tubewell	1,370	1,157	210	3
Total	**1,890**	**1,659**	**226**	**5**

Note: The row total does not tally with Table 9.1 because households that were not willing to pay for and use the arsenic mitigation technologies have not been included in this table.
AMT = arsenic mitigation technology; H = household-based; C = community-based

Figure 9.2: Percentage of households preferring piped water supply to arsenic mitigation technologies — A comparison of users and non-users of arsenic mitigation technologies



There were no significant differences in the responses of the households (Figure 9.2). Over 90 percent of the households that had no experience of the technologies preferred piped water supply to arsenic mitigation technology (without any capital subsidy on the latter). The proportion was roughly the same for households that had used or were currently using arsenic mitigation technologies. About 90 percent of the households that had used the three-*kolshi* or activated alumina technology, and about 80 percent of the households that had used deep tubewells, expressed a preference for piped water over their most preferred arsenic mitigation technology.

9.2 Analyzing household responses based on the logit model

A logit model was applied to analyze household preferences for piped water supply in relation to each of the six selected technologies. The explanatory variables used in the model were household income, respondent's level of education, dummy variables to represent the household's most preferred arsenic mitigation technology (as piped water and the most preferred arsenic mitigation technology were being compared), dummy variables for the districts,[43] a dummy variable to represent whether the household had invested in a tubewell in the last five years, and variables representing household awareness of arsenic toxicity and the perceived advantages of a piped water supply. As mentioned in the earlier section, households were asked to choose between piped water supply and arsenic mitigation technologies under two conditions: if no capital subsidy was provided for arsenic mitigation technologies, and assuming that there was an 80 percent capital subsidy on the technologies. Consequently, two observations were used for each household, and a dummy variable for capital subsidy on arsenic mitigation technologies was included in the model as an explanatory variable.

The results of the model indicate that the preference for piped water increases with the respondent's level of income and education (Table 9.4), which is consistent with the results of the multinomial logit model applied to analyze willingness to pay for piped water (presented in Chapter 8).

The model also suggests that the preference for piped water supply decreases with the increase in the level of subsidy provided for arsenic mitigation technology (Table 9.4). The preference for piped water was found to be directly related to knowledge of the serious health effects of arsenic contamination. Households that considered piped water to be more convenient or better for health had a stronger preference for that technology. The preference for piped water was relatively lower among households that had invested in a new tubewell in the last five years than those households that had not made such an investment.

The coefficients of the dummy variables for Chandpur and Chapai Nawabganj were positive and statistically significant. This suggests that there is a higher preference for piped water over arsenic

[43] The differences in the conditions prevailing in the three districts in terms of the quantity and quality of water available may influence the respondents' choice between piped water and arsenic mitigation technologies. To capture these effects, dummy variables for the districts were introduced in the logit model.

Table 9.4: Choice between piped water supply and arsenic mitigation technologies — Results of the logit model

Number of observations = 4,664

Explanatory Variable	Coefficient	t-ratio
Subsidy (dummy)	-0.7452	-8.098*
Household income (Tk '000)	0.0761	4.566*
Education of respondent (codes 1 to 6) (1 = illiterate to 6 = graduate and above)	0.0781	2.289*
Households that had invested in a tubewell in the last five years	-0.1953	-1.437
Households that		
Were aware of the serious health effects of arsenic	0.5547	5.441*
Were facing arsenic contamination in the drinking water	0.2869	1.810#
Consider piped water convenient/good for health	0.2189	1.942#
Dummy variables for technologies		
Three-*kolshi*	-1.8879	-5.442*
Activated alumina (household-based)	-1.8188	-4.945*
Dugwell	-1.8082	-3.873*
Pond sand filter	-2.4305	-5.933*
Deep tubewell	-2.8547	-12.460*
Subsidy* (three-*kolshi*)	-0.3821	-1.190
Dummy variables for districts		
Chapai Nawabganj	2.2162	17.413*
Chandpur	0.4546	4.232*
Constant	2.8299	10.623*
LR Chi^2 (15)	906.90	

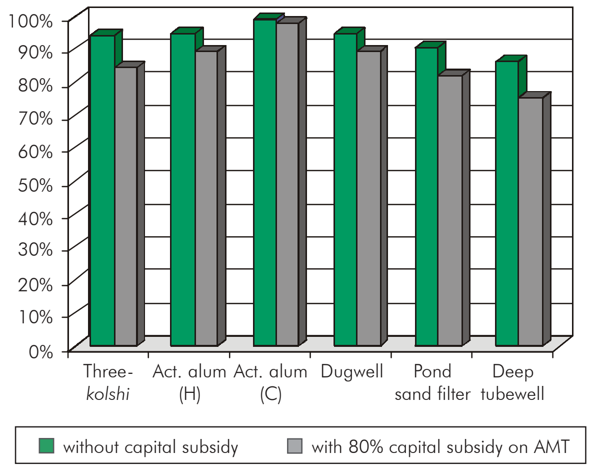
Note: Two observations were used for each household (with and without subsidy on arsenic mitigation technologies). Households that did not select any of the technologies or were not interested in piped water were excluded.
The dependent variable takes the value 1 if piped water supply is chosen by the respondent or otherwise 0.
The dummy variables for technologies represent a household's preferred arsenic mitigation technology. To estimate the model, one of the technology dummies and one of the district dummies have to be excluded. Activated alumina (community-based) and Barisal were taken as the excluded categories.
** Statistically significant at 5 percent or higher level.*
 # Statistically significant at 10 percent level.

mitigation technologies in Chapai Nawabganj and Chandpur than in Barisal. This is consistent with the survey results reported in Table 9.1 (see also Figure 9.1).

9.3 Estimating the probability of choosing an arsenic mitigation technology over piped water systems

The logit model was used to estimate the probability of a household choosing a piped water system over an arsenic mitigation technology (Figure 9.3). The results show that there was a strong preference for piped water supply over arsenic mitigation technologies. The probability of opting for piped water supply over a deep tubewell without any provision of subsidy was about 85 percent. In relation to the other five technologies, the probability was over 90 percent. With an 80 percent capital subsidy on arsenic mitigation technologies, the probability of choosing one of these over piped water increases, but continued to remain lower than 25 percent (less than 20 percent for technologies other than deep tubewells).

Figure 9.3: Probability of choosing a piped water system over arsenic mitigation technologies



The probability of opting for piped water over a deep tubewell was lower than the probability of opting for piped water over the three-*kolshi* method or activated alumina technology (both with and without capital study for arsenic mitigation technologies) (see Figure 9.3). Similarly, the probability of opting for piped water over a deep tubewell was lower than the probability of opting for piped water over dugwells or pond sand filters. One possible interpretation of these results is that from the point of view of a typical household, the disadvantages of using other arsenic mitigation technologies vis-à-vis piped water were greater than the disadvantages of using a deep tubewell vis-à-vis piped water. This is consistent with the conclusion in Chapter 7 that deep tubewells were considered the preferred option among the six selected arsenic mitigation technologies considered in the study.

9.4 Summing up

The survey results show that even though piped water supply entails much higher expenditure, households in rural Bangladesh prefer these systems to arsenic mitigation technologies. The main reasons given by respondents for this choice were convenience and the possibility of accessing water free of arsenic and bacteriological contamination.

An increase in the level of subsidy for arsenic mitigation technologies results in a decrease in the preference for piped water supply. Household income, respondent's level of education, knowledge of the serious health effects of arsenic contamination, and the perceived advantages of piped water systems were found to be positively related to the preference for piped water. This preference was stronger in Chapai Nawabganj and Chandpur than in Barisal. Indeed, in Barisal, nearly 40 percent of the respondents expressed a preference for arsenic mitigation technologies (primarily deep tubewells) over piped water when this choice was offered with 80 percent capital subsidy for arsenic mitigation technologies. From these findings it appears that while there was an overwhelming preference for piped water, a significant percentage of households in some regions may prefer other options.

The estimated probability of choosing piped water systems over arsenic mitigation technologies was high both with and without subsidy. This reflects the strong demand for piped water in rural Bangladesh, which in most areas does not weaken even if large capital subsidies are given to arsenic mitigation technologies.

10 Does the Provision of Safe Public Tubewells in Arsenic-Affected Areas Reduce the Demand for Piped Water?

In some arsenic-contaminated areas of Bangladesh, a large number of households have in recent years shifted their drinking water source from private tubewells to deep public tubewells that provide safe arsenic-free water. The survey fielded in the sample and control areas was also canvassed in these areas to establish whether households that are accessing safe arsenic-free water would prefer piped water as an alternate source of water supply. The extent to which they would be willing to share the cost of setting up and operating such schemes was also assessed.

In this phase of the study, 150 households were surveyed in five villages in Banaripara *thana,*[44] Barisal district. Thirty households were randomly chosen from each village. The econometric model applied to the data for the sample and control areas (see Chapter 8 and Annex B) was used to analyze household preferences and to estimate the mean willingness to pay in Banaripara. This chapter presents the findings and compares them with the findings of the analysis of preferences and willingness to pay in the sample and control areas.

10.1 Socio-economic profile of the respondents

The socio-economic profile of the respondents in Banaripara was similar to that of the respondents in the arsenic-affected sample areas covered in the survey (for a comparative listing, see Table 10.1). However, there were differences in some of the indicators. Average income, reflected in the proportion of houses with an electricity connection and average expenditure on electricity, was slightly lower in Banaripara than in the sample area.[45] The proportion of households where the head was engaged in business or in service was slightly higher in Banaripara than in the sample area.

[44] Banaripara was selected for the study because though the area faces a problem of groundwater arsenic contamination, most people were not exposed to arsenic poisoning as they had shifted to public tubewells.
[45] The proportion of households with a monthly income above Tk 10,000 was 1.3 percent in Banaripara as compared to 4.6 percent in the sample area.

Table 10.1: Socio-economic profile of the respondents in Banaripara and the sample area

Indicator	Banaripara	Sample area
Proportion of male respondents (%)	96	92
Average age (years)	47.9	42.2
Percentage of respondents with education above Class X	14	21
Average income (Tk/month)	3,866	4,588
Percentage of poor households*	53	57
Percentage of households with an electricity connection	21	31
Average expenditure on electricity (Tk/month)	16.2	47.8
Average family size (No. of members)	6.0	6.1
Percentage of households where the head is a farmer	38	39
Percentage of households where the head is in service or business	51	41

** Defined as earning less than Tk 3,600 per month.*

Table 10.2: Water consumption (liters per day per household)

Purpose	Dry season		Wet season	
	Banaripara	Sample area	Banaripara	Sample area
Drinking	33.3	31.9	33.6	32.2
Cooking	51.7	50.4	50.4	51.0
Bathing	172.0	151.0	156.8	157.0
Others*	116.9	105.4	111.9	110.0
Total	**373.9**	**338.7**	**352.7**	**350.2**
Average family size (No. of members)	6	6.1	6	6.1
Per capita consumption	62.3	55.5	58.8	57.4

** For example, washing clothes.*

10.2 Reported extent of arsenic-contaminated tubewells and shift to an alternate drinking water source

About 95 percent of the households surveyed in Banaripara reported that the tubewell nearest to their house had been tested for arsenic. Households also reported that out of the tubewells tested, about 29 percent were contaminated. None of the households surveyed in Banaripara were using tubewells that were contaminated.

These findings are contrary to the results for the sample area. Fewer households (58 percent) in the sample area reported that the tubewell nearest their house had been tested, even though the incidence of arsenic contamination was considerably higher (61 percent of the tubewells were found to be contaminated) (see Table 6.17). Moreover, a number of households (about 15 percent of the total sample) were continuing to use arsenic-contaminated tubewells.

In Banaripara, out of the 33 households that had changed their drinking water source in the three years preceding the survey due to arsenic contamination, 30 had shifted from a domestic tubewell to a public tubewell. This shift had resulted in an increase in the distance to be traveled from 51 feet to 676 feet. As a consequence, the time required to collect drinking water had also increased from 5 minutes to 22 minutes. A similar increase in time and distance as a result of a shift in drinking water source was noted earlier in the sample area (see Chapter 6, Section 6.5) where the average distance had increased from 84 to 556 feet and the average time had increased from 9 to 27 minutes.

10.3 Water sources and uses

Patterns of water consumption were similar in Banaripara and the sample area (Table 10.2). On an average, each household used about 374 liters of water each day in the dry season, of which 33 liters were for drinking. The figures for the wet season were similar.

There were some differences with regard to sources of drinking water across the areas (Table 10.3). Although households in both Banaripara and the sample area face the problem of arsenic contamination, most households (approximately 87 percent) in Banaripara were using water from public tubewells for drinking (Table 10.3). This reflects the large-scale shift households have made in their drinking water source in response to the arsenic problem. In contrast, fewer households in the sample area (about 57 percent) were using public tubewells as their source of drinking water. Interestingly, while some households (about 2.5 percent of the total households surveyed, see Figure 6.2) in the sample area had shifted to ponds and tanks as a source of drinking water because the tubewells were contaminated with arsenic, in Banaripara there had been no such shift to these sources. However, most households in both Banaripara (70 percent) and the sample area (60 percent) were using ponds and tanks as the main source of water for cooking.

10.4 Estimated willingness to pay for piped water supply in Banaripara

A multinomial logit model, similar to the model used to analyze data in the sample and control areas (see Chapter 8), was applied to estimate household preferences for piped water and mean willingness to pay (see Table 10.4). The model was estimated using a number of alternate specifications (in terms of the explanatory variables to be included in the equations), and the specification that yielded best results was finally selected for interpretation and estimating mean willingness to pay (see Table 10.4).[46]

Table 10.3: Source of drinking water

Source	Dry season		Wet season	
	Banaripara	Sample area	Banaripara	Sample area
Dugwell (Public)	0 (0.0)	4 (0.2)	0 (0.0)	4 (0.2)
Dugwell (Private)	1 (0.7)	6 (0.2)	1 (0.7)	5 (0.2)
Pond/Tank	0 (0.0)	128 (5.3)	0 (0.0)	130 (5.3)
Tubewell (Domestic)	16 (10.7)	881 (36.3)	16 (10.7)	888 (36.5)
Tubewell (Public)	131 (87.3)	1,395 (57.4)	131 (87.3)	1,379 (56.7)
Canal/Stream/Others	2 (1.3)	83 (3.4)	2 (1.3)	101 (4.2)
Total households	**150**	**2,430**	**150**	**2,430**

Note: Some households were using more than one source of water.
Figures in brackets are percentages.

[46] In the estimated model for the sample area (see Table 8.3), education of the respondent and occupation of the household heads were included as explanatory variables as these were found to have a significant effect on the choices made by the respondents. However, in the preliminary estimates of the model for Banaripara, these variables were statistically insignificant in explaining household preferences and were, therefore, not included in the final model.

Table 10.4: Results of the multinomial regression model to explain household choices regarding piped water in Banaripara

No. of observations = 150

Explanatory variable	Public standpost		Domestic connection	
	Coefficient	t-ratio	Coefficient	t-ratio
Income (Tk '000)	3.1274	3.82*	3.2408	3.96*
Charge for standpost	-0.1891	-3.70 *		
Charge for domestic connection			-0.0969	-3.74*
HH that consider piped water more convenient	3.5092	3.25*	2.2583	2.00*
Changed drinking water source in the last three years	2.3995	1.61	2.8231	1.85#
Getting drinking water from public tubewell	3.5723	2.53*	3.1276	2.16*
Constant	-3.8941	-2.01	-2.9874	-1.51
LR Chi^2 (10)	85.66			

** Statistically significant at 5 percent or higher level.*
 # Statistically significant at 10 percent level.

The results were as expected and in agreement with the results obtained for the sample and control areas (see Tables 8.3 and 8.7). Income had a positive impact on the demand for piped water while the charges to be paid for this facility had a negative effect on demand (see Table 10.4). As in the sample and control areas, convenience was an important factor influencing the demand for piped water in Banaripara. The demand for piped water was higher among households that considered convenience to be a major advantage of a piped water system (Table 10.4). The households that had recently shifted to public tubewells were relatively more inclined to opt for piped water than other households perhaps because of the extra distance and time that would need to be spent to collect drinking water from public tubewells.

In Banaripara, mean willingness to pay was Tk 1,382 as the initial capital cost of a standpost and Tk 63 per month as O&M. Households were, on an average, willing to pay Tk 2,482 as the initial capital cost and Tk 126 as O&M for a domestic connection (Table 10.5). As a percentage of monthly income, households were willing to pay 1.6 percent of their monthly income as O&M charges for public standposts and 3.3 percent of their monthly income as O&M charges for domestic connections. Households were willing to contribute an average of 3.0 percent of their annual income towards the capital cost of a public standpost and 5.4 percent of their annual income for the capital cost of a domestic connection.

There was a significant difference in the amount that poor and non-poor households in Banaripara were willing to pay for piped water schemes. Poor households were willing to pay only about half the amount non-poor households were willing to pay. However, as a percentage of income, there was not much difference in the willingness to pay between poor and non-poor households. Poor households were, on an average, willing to contribute 1.9 percent of their monthly income as the O&M charges of standposts and 3.6 percent for a domestic connection. Non-poor households were willing to contribute 1.5 percent of their monthly income as the O&M cost of standposts and 3.1 percent for a domestic connection (Table 10.5). Poor households were willing to pay 3.4 percent of their annual

Table 10.5: Estimated mean willingness to pay for piped water in Banaripara

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital cost (Tk)	O&M (Tk/month)	Capital cost (Tk)
Poor	42	923	82	1,626
Non-poor	86	1,895	174	3,439
All	**63**	**1,382**	**126**	**2,482**
Willingness to pay as a percentage of income*				
Poor	1.9	3.4	3.6	6.0
Non-poor	1.5	2.8	3.1	5.1
All	**1.6**	**3.0**	**3.3**	**5.4**

** Annual income was used to compute this ratio with respect to contribution to capital cost. Capital cost is a one-time payment.*

income towards the initial capital cost of a standpost and 6.0 percent for a domestic connection. Non-poor households were willing to pay 2.8 percent and 5.1 percent of their annual income for a standpost and domestic connection, respectively (Table 10.5).

If the mean willingness to pay is compared with the actual capital and O&M cost of a piped water supply scheme, the findings show that, on an average, the respondents were willing to pay more than the actual cost (Table 10.6). The average willingness to pay was 70 percent higher than the actual cost of O&M for standposts, and 94 percent more than the actual cost of a domestic connection. Among poor households, mean willingness to pay for standposts exceeded the O&M cost by more than 14 percent while the mean willingness to pay for a domestic connection exceeded the actual O&M cost by 26 percent. Non-poor households were willing to pay more than twice the actual O&M cost for both standposts and domestic connections.

Rural households in Banaripara were willing to pay more than 10 percent of the actual capital cost of a piped water scheme (Table 10.6). Mean willingness to pay for all households was 22 percent of the capital cost for a standpost and 20 percent for a domestic connection. Non-poor households were willing to pay 30 percent of the capital cost for a standpost and 28 percent for a domestic connection. Poor households were willing to contribute, on an average, 15 percent of the capital cost for a standpost and 13 percent for a domestic connection.

Although the estimates for Banaripara are based on a limited sample of 150 households, it may be possible to infer from the results that there is a strong preference

Table 10.6: Willingness to pay as a percentage of estimated actual cost in Banaripara (percent)

	Public standpost		Domestic connection	
	O&M	Capital cost	O&M	Capital cost
Poor	114	15	126	13
Non-poor	232	30	268	28
All	**170**	**22**	**194**	**20**

Note: As Banaripara is in Barisal district, the cost estimates for Barisal were used (see Annex C). The estimated O&M and capital cost for a standpost is Tk 37 per month per family and Tk 6,250 per family, respectively. The corresponding cost for a domestic connection is Tk 65 per family per month and Tk 12,500 per family, respectively.

Figure 10.1: Mean willingness to pay for the O&M cost of piped water: A comparison of Banaripara with the sample and control areas

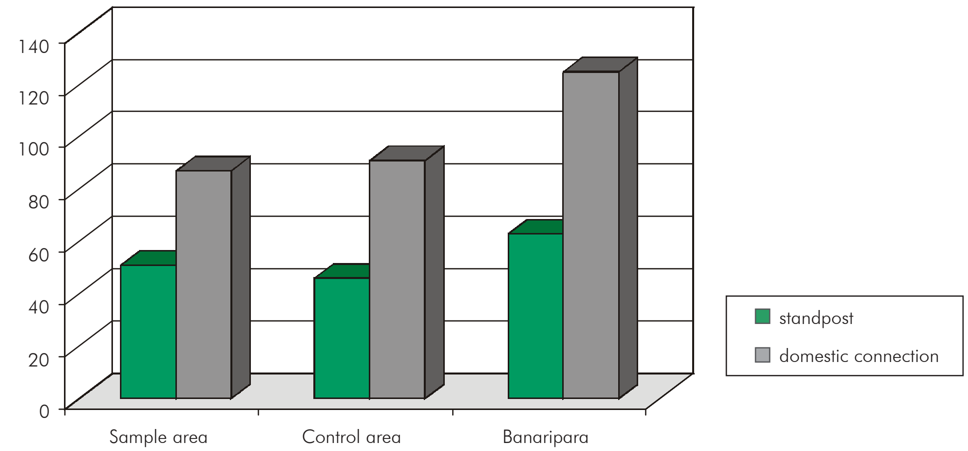
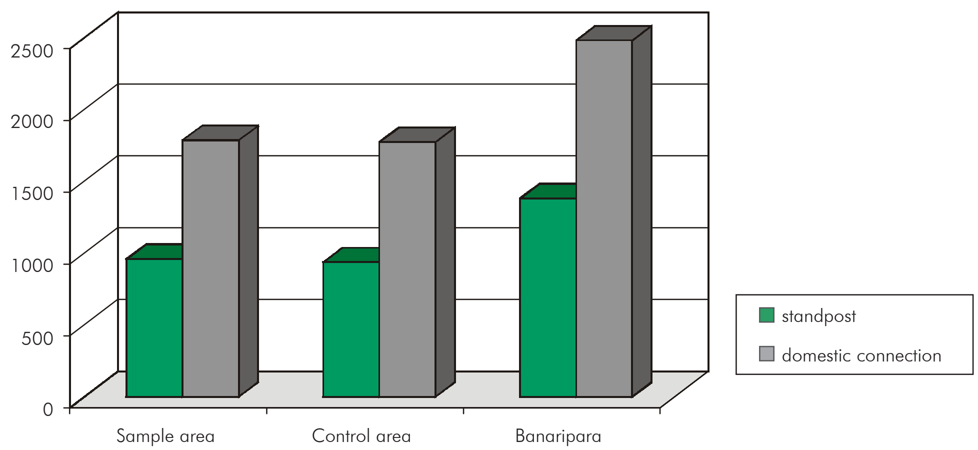


Figure 10.2: Mean willingness to pay for the capital cost of piped water: A comparison of Banaripara with the sample and control areas



for piped water in this area. The availability of public tubewells in this area has not made the option of piped water less attractive. This is primarily due to the convenience that households expect from piped water supply, especially because many households at present travel long distance and spend extra time collecting water from public tubewells.

10.4.1 A comparison of the willingness to pay in Banaripara with the sample and control areas

Compared to the sample and control areas, households in Banaripara were, on an average, willing to pay more for piped water (Table 10.7; Figures 10.1 and 10.2). In Banaripara the mean willingness to pay was Tk 1,382 as the initial capital cost of a standpost and Tk 63 per month as O&M. The corresponding figures for the sample area were Tk 960 as initial capital cost and Tk 51 per month for O&M, and Tk 937 and Tk 46 per month, respectively, in the control area. For a domestic connection, households in Banaripara were willing to pay on an average Tk 2,482 as the initial capital cost and Tk 126 for O&M. The corresponding figures were Tk 1,787 as initial capital cost and Tk 87 per month as O&M charges in the sample area and

Table 10.7: Willingness to pay (WTP) for piped water in Banaripara compared to the sample and control areas

	Public standpost			Domestic connection		
	Banaripara	Sample area	Control area	Banaripara	Sample area	Control area
WTP						
O&M (Tk/month)	63	51	46	126	87	91
Capital cost (Tk)	1,382	960	937	2,482	1,787	1,775
WTP as % income						
O&M	1.6	1.1	1.0	3.3	1.9	2.0
Capital cost	3.0	1.7	1.7	5.4	3.2	3.2
WTP as % actual cost of supply						
O&M	170	146	135	194	140	152
Capital cost	22	18	20	20	17	19

Tk 1,775 and Tk 91 per month, respectively, in the control area.

The estimates suggest that compared to the sample and control areas, households in Banaripara were willing to pay a higher percentage of their income for piped water. Similarly, the average willingness to pay as a percentage of actual cost of piped water supply was also higher. It should be noted, however, that there was relatively little difference between Banaripara and the sample and control areas with regard to the percentage of the initial capital cost households were on an average, willing to pay (see Table 10.7). In Banaripara, households were willing to pay on an average 22 percent of capital cost of a standpost and 20 percent of the capital cost of a domestic connection. The relevant proportions were 18 and 17 percent, respectively, in the sample area and 20 and 19 percent, respectively, in the control area.

10.5 Summing up

The findings show that even in arsenic-contaminated areas where there has been a large-scale shift to public tubewells due to the arsenic-problem, there is a strong preference for piped water supply. Although the construction of deep public tubewells has provided access to arsenic-free drinking water, households prefer piped water from a public standpost nearer their house or a domestic connection because they have to travel longer distances and spend more time to collect drinking water from a public tubewell. Households in these areas were willing to cover the O&M cost of a piped water supply as well as to contribute more than 10 percent of the capital cost of piped water supply schemes.

As mentioned earlier, 10 percent is often the stipulated share of beneficiary households in capital cost of rural piped water supply projects. It appears from the results that it would be possible for households in Banaripara to meet this level of capital cost.

The findings presented in this chapter highlight the fact that though households in Banaripara already have access to safe arsenic-free water, the value of piped water in this area (as reflected in the mean willingness to pay) is not less than that of the households in the sample area. This confirms the findings of the sample and control areas (presented in the earlier chapters) that the demand for piped water is essentially driven by the convenience that these systems offer.

Extrapolating from the Study

11

This study was specially designed in the context of the widespread problem of arsenic contamination in rural Bangladesh to gather information on household perceptions about the arsenic problem. The study explores the current solutions being offered and assesses people's willingness to pay for arsenic-free safe drinking water options. It also investigates the factors that influence the demand for arsenic-free safe drinking water and examines household preferences among various arsenic mitigation technologies. The perceived advantages of piped water supply systems, the demand for piped water in rural areas, and whether households prefer such systems to other arsenic mitigation technologies are other issues that have been explored. The findings of the study are discussed in detail in the report.

The conclusions of this study, drawn from information provided by the communities themselves, could assist policy makers to evolve a framework to address the arsenic crisis. *First*, and perhaps the most important, is that unless household-level filtering systems become affordable, convenient to use, and easy to link to shallow tubewells, the 'water miracle' in Bangladesh may be reversed. The convenience offered by shallow tubewells will make it difficult to promote alternative solutions like ponds and dugwells. Alternatives to tubewells would need to provide access to safe water as well as the convenience of tubewell technology.

The *second* conclusion to emerge from the study is the strong household preference for piped water systems. The density of rural settlements in Bangladesh and the growth of rural incomes over the last two decades may have made piped network systems more affordable. Piped water systems, with their central treatment facility, are more effective than household-level technologies in addressing arsenic contamination as the system can be managed and monitored from a central location. Moreover, the technology used for treatment can be easily upgraded at a central point whenever required. Another advantage of a central filtration system is that it allows for the treatment of pathogenic contamination of surface water, which may enable rural communities to return to the use of surface water that is free of arsenic contamination, but in the context of a more convenient technology.

However, the option of rural piped water systems has been underplayed in Bangladesh. This may be due to the failure to sustain such systems in other South Asian countries, possibly on account of the organizational structures through which these systems have been implemented rather than issues of technology and affordability. In India, for instance, piped water has been delivered through top-down, public sector engineering departments that have traditionally implemented a 'Rolls-Royce' version of piped water systems, with little emphasis on community management or user charges, which has resulted in a high failure rate. The Government of India has now introduced a US$ 350 million program to finance alternative, community-oriented systems that are linked to *panchayati raj* institutions (local government bodies) to deliver drinking water in rural areas. The program provides 90 percent of the capital cost for community-based systems while households pay 10 percent of the capital cost and the entire O&M or recurrent cost.

In this context, the policy challenge facing Bangladesh in exploring the potential of piped water systems in rural areas is to assess the feasibility of delivering these systems through alternative organizations that are responsive to rural consumers. In particular, it is important to assess the potential of delivering network systems through independent (non-public) service providers. Bangladesh's experience with rural cooperatives managed by the Rural Electricity Board and service delivery through NGOs in areas as diverse as education and micro-credit suggests that Bangladesh has local organizations that can play the role of such service providers. Indeed, the piped water network systems introduced by the Rural Development Academy in the Bogra area suggest the potential of such systems in Bangladesh.

The estimates of willingness to pay obtained in this study indicate the possibility of introducing a demand-driven program to expand rural drinking water systems similar to the program currently being implemented in India, with the potential of raising an even higher contribution from households. This hypothesis can only be tested by actively promoting piped water pilots on the ground to enable active learning or action research to complement the assessment provided through this study. The preliminary results of this study have, in fact, already prompted the development and design of several piped water pilots. A comparison of the results of the pilots and the findings of this study will provide further inputs to policy makers on the way forward in addressing the arsenic crisis.

Although there is a strong preference for piped water, households should not be offered a one-point solution as a significant number of households may prefer other technologies. This is the *third* conclusion of policy relevance from this study. While the areas sampled in this study broadly reflect the socio-economic profile of rural Bangladesh, there are some areas where the population density and income levels may warrant a household technology. Keeping the option of choice open is important, especially in a context where technologies and technology cost may be constantly changing. It should be noted from the findings of this study that the preference for piped water is driven more by the factor of convenience than by the issue of arsenic contamination, reflecting perhaps a growing structural shift in the preferences of rural households for water services. This shift is largely independent of the arsenic crisis but nevertheless strengthened by it.

The *fourth* important conclusion is the need for dissemination of information. In view of the magnitude of the crisis that Bangladesh is currently facing, households require to be given extensive information on arsenic contamination, its serious health effects, and possible technology options. The issues of dissemination of information, ensuring choice and options, monitoring of water quality (which was ignored in the context of handpump technology) and most importantly managing the introduction of a network system have various elements of public goods. This suggests that the arsenic crisis is bringing 'public goods and government' back into the drinking water sector. These dimensions of the arsenic crisis clearly raise the issue of the role of local governments in the drinking water sector in Bangladesh.

In the unitary structure of government in Bangladesh, local governments have not been given the space to emerge as key players in the management of service delivery at the local level. Yet, by nature, local governments are closest to a crisis of the kind being experienced in the drinking water sector where alternative solutions will be specific to local contexts. The arsenic crisis has opened the door to rethink the role of local government in Bangladesh. Can local governments be empowered to manage a community-based response to the arsenic crisis? Can local governments support the emergence of independent service providers in rural areas, thus drawing on existing NGO capacity? These are critical issues of local governance being brought out as a direct result of the arsenic crisis.

Another issue indirectly raised by the study is the significance of monitoring water quality. In the euphoria of the private sector-led approach to drinking water delivery, the issue of monitoring water quality was largely ignored in Bangladesh. Arsenic contamination has now raised the issue of institutionalizing mechanisms to monitor water in the country. Establishing standards, creating an independent water regulatory agency, developing a monitoring process, and linking this with local governments are policy issues that have to be addressed even as immediate solutions to the arsenic crisis are developed.

Annex A (Notes I–IV) Survey Method and Sampling Strategy

Note I: Instructions to supervisors and enumerators on the willingness to pay questionnaire

General instructions:

1. The questionnaire should be filled completely.
2. The correct boxes should be ticked to avoid ambiguity.
3. The bullet points should be read out to the respondent to help the respondent answer the questions asked.
4. Figures should be written in English not Bengali.
5. In each household, the interview should be conducted with the head of the household. If the head of the household is not available, the interview could be conducted with a responsible adult male member of the family, for instance a son who is an earning member of the family. The interview should not be conducted with women members of the family, as far as possible, except in the case of female-headed households.

Question specific instructions to supervisors and enumerators:

(For a number of questions detailed instructions were given to the supervisors/enumerators. The instructions for some important questions are summarized below.)

Water use

Question 2.1: Record the quantity of water used by the family per day for different purposes. Add the quantities used for different purposes to get the total water consumption. This is to be filled in both *kolshis* (pitchers) and liters. Indicate (at the appropriate place in the questionnaire) the size of the *kolshi* that the respondent is using. Ensure consistency between the size of the *kolshi* indicated by you and the quantity of water reported in *kolshis* and liters. For households that use surface water sources, such as ponds and rivers, it may be difficult for the respondent to provide information on the quantity of water used for bathing and washing. Ask the respondent what the approximate quantity of consumption would be if they were to fetch the water in a bucket/pitcher for bathing or washing. Under 'other uses', include water used for animals, gardening, etc.

Additional water requirement

Question 2.3: Note that the figures to be recorded are the additional water consumption of the household. The respondent will make a judgment on how much their water consumption will go up if they could get water more easily. This information is to be obtained for the dry season and wet season separately.

Symptoms of arsenicosis

Question 3.3: Ask the respondent to tell you about the symptoms of arsenicosis. After listening to him/her, assess the respondent's knowledge of the symptoms. Record your assessment at the appropriate place in the questionnaire. Then show the respondent Card 1 and explain the symptoms of arsenicosis.

Health risks and treatment cost of arsenicosis

Question 3.11: Inform the respondent correctly about the health risks and the cost of arsenicosis treatment. Use Card 2 (H) and then Card 2 to provide the information. (Read these cards carefully before the survey, and if there are questions ask your supervisor.) Do not forget to tell the respondent that once arsenicosis has reached an advanced stage, it cannot be cured by treatment.

Use of contaminated tubewells

Question 4.17: Ask the respondent why he/she is continuing to use the tubewell when the water is known to be contaminated. More than one answer is possible so you may tick more than one answer.

Choice between household-based and community-based arsenic mitigation technologies

Question 5.2: Note that the respondent is asked to especially consider convenience when choosing between two types of arsenic mitigation technologies. The cost of the technologies is not to be considered. Ask the respondent not to consider cost, only consider the convenience in using the technologies.

Ranking of the six selected arsenic mitigation technologies

Question 5.5: In this question, the respondent is asked to make a choice between the arsenic mitigation technologies, taking into consideration the health risks, income, cost of technologies, etc. Show Card 9 to remind the respondent of the cost and other information about the technologies that were provided earlier.

Affordability of arsenic mitigation technology and capital subsidy

Questions 5.7-5.10: These questions are applicable only if the respondent says that she/he is not willing to use any of the six arsenic mitigation technologies because he/she cannot afford them. The respondent is then asked if he/she would like to use any of the technologies if a 25 percent subsidy is provided on the capital cost of the technology. If the answer is 'no', ask the respondent if he/she would like to use any of the technologies if a 50 percent subsidy is provided on the capital cost of the technology. Note that the subsidy is only on the capital cost not on O&M cost.

Willingness to pay for piped water

Questions 6.5-6.15: A split sampling method will be used. You will be told by your supervisor the charges for piped water you will quote (out of the five set of charges listed).

After the closed-ended question, the respondent is asked to state what is the maximum amount he/she is willing to pay for capital cost. If the respondent is not willing to pay for the capital cost of the piped water scheme (or willing to pay only a very small amount, say Tk 50 or less), then give the respondent the option of contributing to the capital cost of the scheme in terms of labor.

Following the closed-ended question, the respondent is asked what is the maximum amount he/she is willing to pay for O&M cost. Since this question is not followed by a review question, ask the respondent to think carefully before answering.

Choice between piped water and the most preferred arsenic mitigation technology

Questions 6.16 and 6.18: Remind the respondent about the arsenic mitigation technology he/she considers to be the best and the capital cost and O&M cost of the technology. Then remind him/her of the charges for water supply he/she has agreed to pay. Show him/her again the card for piped water systems and the card for his/her most preferred arsenic mitigation technology. Then ask him/her to make a choice between piped water supply and the earlier chosen arsenic mitigation technology. If the respondent says that he/she prefers a piped water supply system to the arsenic mitigation technology, ask him/her whether he/she will choose a piped water system even if there is 80 percent capital subsidy for the arsenic mitigation technology.

Note II: Instructions for selection of survey area

<table>
<tr><th>District</th><th>Thanas/Upazilas</th><th>Villages</th></tr>
<tr><th colspan="3">Actual survey locations</th></tr>
<tr><td>Chapai Nawabganj</td><td>Gomostapur/Nawabganj/ Sadar/Shibganj</td><td rowspan="3">1. Total households to be surveyed in each group of the three upazilas belonging to a district is 800. A total of about 2,400 households will be surveyed in 9 upazilas.
2. The number of households in each upazila will be about 266 (total 800 for 3 upazilas). On an average, there are 200 villages in each upazila. These 200 villages will be divided into five groups and five villages will be randomly selected for the household survey. A <u>stratified random sampling methodology</u> will be used to survey about 54 households in each village.</td></tr>
<tr><td>Chandpur</td><td>Haimchar/Hajiganj/Matlab</td></tr>
<tr><td>Barisal</td><td>Barisal Sadar/Muladi/Ujirpur</td></tr>
<tr><th colspan="3">Control area locations</th></tr>
<tr><td>Chapai Nawabganj</td><td>Bholarhat</td><td rowspan="2">About 300 households will be surveyed in the control area, using stratified random sampling methodology.</td></tr>
<tr><td>Commilla</td><td>Commilla Sadar</td></tr>
<tr><th colspan="3">Arsenic-affected area with large-scale shift to public tubewells</th></tr>
<tr><td>Barisal</td><td>Banaripara</td><td>About 150 households will be surveyed in five villages using stratified random sampling methodology, covering about 30 in each village.</td></tr>
</table>

Note III : Key instructions to supervisors for carrying out the survey work

General instructions:

1. Supervisors should ensure that the questionnaires are filled completely and according to the instructions.
2. At the end of the day, supervisors should check the questionnaires filled by the enumerators. If a questionnaire is found to be incomplete, the enumerator should be asked to make a repeat visit to the house and get answers to the unanswered questions. The supervisor should ensure that, as far as possible, the enumerators get the questionnaire filled completely in the first interview, even if it means spending a little extra time, so that a second visit is not necessary.
3. Supervisors should fill in the daily progress on the prescribed daily tracking sheet (see Note IV).
4. Supervisors should inform BRAC/WSP of any problems that may arise during the field study for necessary advice.
5. The supervisor will be responsible for filling up the village-level questionnaire. This should be done after the household-level survey has been completed.

Instructions on sampling:

In each district, 800 households are to be covered in the survey. The sample is to be divided into five sub-samples, as discussed below and in Note II. In addition, there will be a control area sample of 300 households, covering two districts.

For each district, supervisors will select the villages to be covered in the survey as well as the households to be surveyed in each village. For each district, the *thana*s to be covered in the survey have already been selected by BRAC. Villages under these *thana*s will be selected by random sampling. This will be based on the list of villages with the local BRAC office.

Within each village houses will be selected using interval-based random sampling. For each village, the number of households will first be ascertained. The ratio of the number of households to the number of households to be covered will give the interval to be used for choosing houses for the survey. If, for instance, the ratio is about five, then every sixth house will be chosen for the survey. However, if a responsible adult male member is not available for the interview, the next house will be chosen. Any further instructions to supervisors will be given by BRAC.

On split sampling:

The entire sample of a district is to be divided into five sub-samples of 160 households each, and one set of charges for piped water is to be quoted from the five sets of charges listed in brackets for the close-ended willingness to pay questions.

Each enumerator will be informed about the set of figures to be used when conducting the survey in the sub-sample. He will quote that set of piped water charges for all the households in the sub-sample.

Instructions for the survey in the control area:

For the survey of the control area, 150 households each are to be covered in Bolarhat *thana* of Chapai Nawabganj district and Commilla Sadar *thana* of Commilla district.

When the survey is undertaken in the control area, the following questions are <u>not</u> to be asked:

- Section 5 entirely (questions on arsenic mitigation technologies); and
- Questions 6.16-6.18 (questions on choice between piped water and arsenic mitigation technologies).

These questions should be scored out from the questionnaire before starting the survey in the control area to avoid confusion at the time of the interview.

Note IV : Supervisor's daily tracking sheet

Name of supervisor   Signature of the supervisor

District ———— Village ————

	Date					
	Names of enumerators	Split sample allotted (Type 1-5)	Questionnaires filled	Questionnaires checked by supervisor	Number of households randomly cross-checked (previous day)	Problems, if any, that need to be checked urgently with the task team
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
Total						

Annex B

Methodology of Econometric Estimation of Willingness to Pay

The study and field survey

As mentioned in Chapter 3, a contingent valuation questionnaire was fielded in 2,880 households in rural Bangladesh to assess households' willingness to pay for piped water supply. Two levels of service were envisaged: public standposts (shared connections) and domestic piped water connections. Willingness to pay was estimated for these two levels of service.

For the contingent valuation survey, a split-sampling method was used, as done, for example, in the study on piped water supply for Kathmandu by Pattanayak, et al. (2002).

The total sample for the sample area was divided into five sub-samples.[47] Similarly, the total sample for the control area was divided into five sub-samples. Five different charges for public standposts and domestic connections were quoted in the five different sub-samples. The respondents were asked to make a choice between public standposts and domestic connections. The third choice available to them was to reject both and continue to use the present sources of water. The charges for piped water supply quoted to the respondents in different sub-samples are shown in Table B.1.

Respondents were told that they would have to make a one-time payment for the capital cost of the piped water supply project and a monthly payment for the O&M cost. The amount they would have to pay was indicated during the survey.

Table B.1: Charges for piped water quoted in the survey for different sub-samples

Sub-samples	Public standpost		Domestic connection	
	O&M (Tk/month)	Contribution to initial capital cost (Tk)	O&M (Tk/month)	Contribution to initial capital cost (Tk)
Sub-sample 1	10	200	30	500
Sub-sample 2	20	400	50	750
Sub-sample 3	30	600	70	1,000
Sub-sample 4	40	800	90	2,000
Sub-sample 5	50	1,000	100	3,000

[47] For each of the three districts chosen for the study, three *thanas* from the respective districts were selected. In each *thana*, five villages were randomly chosen. These five villages were then assigned to the five sub-samples, one village for each sub-sample. This ensured that the sub-samples had the same geographical distribution.

Data on a number of socio-economic variables were collected through the survey, which were used to estimate an econometric model. This model was used to explain the choice made by respondents with regard to piped water supply. The model was then used to estimate the average willingness to pay.

The model

A multinomial logit model was used for the econometric analysis.[48] The basic theoretical framework is outlined below, and is followed by a discussion on how the model was applied.[49]

Let the level of water service be denoted by q, a public standpost by q^1, and a domestic piped water connection by q^2. If neither is chosen, the household continues with the current source, which is denoted by q^0. The income (per month) of the household is denoted by y and other socio-economic characteristics of the respondent/household are denoted by vector s.

The utility function associated with the three choices are given by:

Conventional source/no change (baseline utility): $U_0 = v_0 (q^0, y, s, e_0)$

Public standpost: $U_1 = v_1 (q^1, y, s, e_1)$

Domestic piped water connection: $U_2 = v_2 (q^2, y, s, e_2)$

In these functions, e_k is the random component associated with the k'th item or choice.

Let A_1 be the monthly charge for a public standpost and A_2 the monthly charge for a domestic piped water connection. A_0 is defined as zero.

The respondent/household will choose a domestic piped water connection if:

(1) $v_2 (q^2, y\text{-}A_2 , s, e_2) \geq v_0 (q^0, y\text{-}A_0 , s, e_0)$, and

(2) $v_2 (q^2, y\text{-}A_2, s, e_2) \geq v_1 (q^1, y\text{-}A_1, s, e_1)$

The conditions under which he/she will choose a public standpost or choose to continue with the conventional water source can be similarly obtained. In general, the probability of choosing the k'th item is:

(3) $\Pr (\text{k'th item chosen}) = \Pr \{v_k (q^k, y\text{-}A_k, s, e_k) \geq v_i (q^i, y\text{-}A_i, s, e_i), i = 0,1,2\}$

Given the framework described above, the multinomial logit model may be applied to explain the choices and estimate the willingness to pay for piped water supply.

Some simplifying assumptions, however, become necessary to apply the multinomial logit model. A linear structure is assumed for the utility function. Thus, the utility function of the i'th respondent/household for the k'th item may be written as:

(4) $U_{ki} = \beta_k' X_i + e_{ki}$

In this equation, β is the vector of parameters (one vector corresponding to each choice) and X is the vector of income and socio-economic characteristics.

Let Y_i be a random variable indicating the choice made. Assuming that the disturbance terms e_{ki} are independent and identically distributed with Weibull distribution, the probability of k'th item being chosen is:

(5)
$$\Pr ob(Y_i \quad k) \quad \frac{e^{{}_k X_i}}{{}_j e^{{}_j X_i}}$$

This is the multinomial logit model. It is estimated by the maximum likelihood method. A convenient normalization that is done is to assume that $\beta_0 = 0$, that is, the parameter vector for the baseline choice is taken to be zero.

Given the estimates of the parameters and hence the utility functions for each of the possible choices,

48 For earlier applications of the multinomial logit model to assess people's preferences for piped water supply, see Briscoe et al. (1990) and Pattanyak et al. (2002). The multinomial logit model has also found wide application in contingent valuation studies undertaken in other contexts. See, for instance, McFadden (1976). It has been suggested that, in some cases, it may be more appropriate to call the applied model the conditional logit model rather than the multinomial logit model (see Greene, 2000).

49 For a discussion on methodological issues concerning the multinomial logit model, see Greene (2000) and Hanemann and Kanninen (1998).

the compensating variation or the willingness to pay for a particular choice may be derived in the following way.

Compensating variation or willingness to pay for a program is the amount of payment by the consumer such that the utility after provision is the same as in the base case (without the program). Thus, willingness to pay for a domestic piped water connection is given by the amount C that will satisfy the following equality:

(6) $v_2 (q^2, y\text{-}C, s, e_2) = v_0 (q^0, y, s, e_0)$.

Applying the model

To apply the model described above, the following explanatory variables were used:

- Income
- Education
- Occupational category
- Variables representing arsenic perception and concern
- Variables representing the perceived advantages of piped water supply
- Monthly payment for public standposts (capital and O&M combined)
- Monthly payment for a domestic connection (capital and O&M combined)
- Other variables

The dependent variable is the choice made by the respondent: public standpost (1), domestic piped water connection (2), and neither of them (0).

The utility functions underlying the multinomial logit model were specified as:

(7) Conventional source (baseline utility): $U_0 = w_0 (q^0, y, s) + e_0$

(8) Public standpost: $U_1 = w_1 (q^1, y, b_S, s) + e_1$

(9) Domestic piped water connection: $U_2 = w_2 (q^2, y, b_D, s) + e_2$

In these equations, b_S is the monthly charge for a public standpost and b_D is the monthly charge for a domestic connection. Household income is denoted by *y*. The vector s stands for all other socio-economic variables. The household will choose domestic connection if U_2 exceeds both U_0 and U_1 (this follows equations 1 and 2 above). The conditions under which the household will choose a standpost, or reject both a standpost and domestic connection, can be similarly defined. It should be noted that U_1 and U_2 represent utilities from a standpost and a domestic connection respectively, net of the monthly charges paid. Further, the structure of equations is such that monthly charges for a standpost enter the equation for a standpost and the monthly charges for domestic connection enters the equation for domestic connection.

The STATA software package was used to estimate the multinomial logit model. This package allows one to impose restrictions on parameters. Therefore, some variables can be dropped from an equation by restricting its coefficient to zero.

Though two charges were quoted to the respondents in the survey, one for capital cost and the other for O&M cost, these were combined into an equivalent monthly charge for the econometric analysis (to be consistent with the theoretical model in equations 1-6 and the applied model given in equations 7-9). The one-time payment for capital cost was converted into an equivalent monthly payment applying the interest rate, taken as 12 percent per annum.[50] This figure was added to the quoted monthly payment for O&M to estimate the total monthly

[50] In 2001-02 when the survey was conducted, the rate of interest on deposits for two years or more with major banks in Bangladesh was 8 to 9 per cent per annum. The interest rate for agricultural lending in such banks was between 12 to 16 percent per annum. The mid point of the range of interest rates, that is, 12 percent per annum, was used to convert one-time capital cost payment into an equivalent monthly payment. Arguably, the correct interest rate to apply would vary among households depending on their financial position and whether they would pay the initial capital cost out of their savings or would have to borrow money for this purpose. However, due to lack of data, this modification could not be introduced in the estimated model.

payment to be made by households for the facility of piped water supply (separate figures for standposts and domestic connections).

Estimation of willingness to pay from the multinomial logit model

The estimation of the multinomial logit model given above yields estimates of the parameters of functions w_1 and w_2. The coefficients of w_0 are taken as zero by the computer package used for estimation. Thus, if income and other socio-economic variables are kept at the sample average, then the mean willingness to pay for a public standpost is given by that value of b_S (the monthly charge for a public standpost), which satisfies the following equation:

(10) $w_1 (q^1, y, b_S, s) = 0.$

Let this value be denoted by b_S^*. Then,

(11) Average willingness to pay for a public standpost $= b_S^*$.

Similarly, one can find the value of b_D, which satisfies the following equation:

(12) $w_2 (q^2, y, b_D, s) = 0.$

Let this value be denoted by b_D^*. Then,

(13) Average willingness to pay for a domestic piped water connection $= b_D^*$.

To calculate the average willingness to pay for sub-groups of households, for example, poor and non-poor households or households belonging to a particular district, the average value of income and other socio-economic variables were computed, and equations (10) and (12) applied. This process indicates the total amount that households were willing to pay per month. In the next step, this was split into (1) willingness to pay for O&M cost, and (2) willingness to pay for capital cost. This was based on the responses obtained to the open-ended valuation question (after the respondent was asked the closed-ended question he/she was asked two open-ended questions: what is the maximum he/she is willing to pay towards capital cost and what the maximum he/she is willing to pay towards O&M cost) as explained below.

Based on the responses to the open-ended question, the ratio of willingness to pay for O&M to that for capital cost was computed. Let this ratio be denoted by R. Then, the willingness to pay for O&M [$WTP_{O\&M}$] for a standpost and the capital cost [WTP_{CAP_COST}] of a standpost should satisfy the following two equations:

$$b_S^* = WTP_{O\&M} + 1 \text{ percent of } WTP_{CAP\_COST}$$

$$R = WTP_{O\&M} / WTP_{CAP\_COST}$$

Since values of b_S^* and R are known, the above two equations are solved simultaneously to obtain $WTP_{O\&M}$ and WTP_{CAP_COST}.

In a similar manner, the willingness to pay for capital cost and O&M cost of a domestic connection was computed.

Annex C

Cost of Piped Water Supply in Rural Bangladesh

Based on a detailed study of the cost data of four rural piped water supply projects in Bangladesh — RDA, Bogra; WPP, Rajshahi; rural water supply project in Barind area, Barind Multipurpose Development Authority; and BRAC piped water supply project at Narayanganj — and consultations with DPHE on deep tubewell areas, the Dhaka Office of the Water and Sanitation Program estimated the cost of piped water supply in rural Bangladesh for three hydrogeological zones. The sources used for this purpose were:

- The technical design of the WSP-WPP rural piped water project in Rajshahi, 2002 (low water table area);
- Personal communication with RDA on the rural piped water project of BRAC in Sonargaon *upazila*, Narayanganj, 2002 (shallow water table area);
- The action research project report on Bhashubihar project, Bogra, RDA, 2000 (low water table area);
- The Project Concept Paper on rural piped water supply in Barind area (Rajshahi, Nawabganj, Naogaon), Barind Multipurpose Development Authority, May 2002; and,
- Personal communication with DPHE on deep tubewell areas as there are no rural piped water systems in these areas.

The cost estimates are shown in Table C.1.

The capital cost estimates listed in Table C.1 are lower than the capital cost estimates of some recent rural water supply projects in India (in the Karnataka rural water supply project, the cost of piped water supply is expected to be about Rs. 1,500 to 2,000 per capita, or between Rs. 9,000 to 12,000 per household). This difference in capital cost can be explained. For one, the cost estimated for rural Bangladesh is based on direct implementation of projects. Procurement through a government system could result in considerably higher cost (at least 30 percent cost escalation). Secondly, high population

Table C.1: Cost estimate for piped water supply in rural Bangladesh

Hydrogeological zone	Capital cost per household (in Taka)		O&M cost per household (in Taka per month)		Remarks
	Range	Average	Range	Average	
1. Shallow tubewell area	3,200-5,000	4,000	30-60	45	The cost variation in deep tubewell areas is primarily due to the higher installation cost of borewells and higher cost of pumping.
2. Low water table area	3,200-5,000	4,000	30-60	45	
3. Deep tubewell area	5,000-7,000	6,000	40-60	50	

density and proximity to the sources in Bangladesh makes the cost of setting up a piped water supply more economical.

It is felt that the average capital cost figures in Table C.1 should not be used to estimate the capital cost of a domestic piped water connection in the study. Instead, the estimate of capital cost should be based on the upper limit of the range indicated. The reasons are as follows:

- The cost per household or per connection in some of the projects studied is currently much higher than the cost indicated in the table. For example, in the BRAC Narayanganj project, the capital cost per connection is about Tk 17,000, which is expected to reduce to Tk 5,600 when there is full design capacity utilization.
- The purpose of calculating the cost of piped water supply in rural Bangladesh is to compare these estimates with people's willingness to pay and analyze issues connected with cost recovery. From this point of view, it would be better to take a conservative cost estimate because if the analysis indicates adequate cost recovery for such cost estimates, this will also be true for lower cost of piped water supply.

Another point to be noted in this context is that the estimates shown in Table C.1 are based on the assumption of full design capacity utilization. However, if the utilization remains limited to 80 percent, which is more reasonable to expect, then the cost per connection would probably be higher by about 20 to 25 percent.

The estimate of capital cost, based on these considerations, has been worked out in the following way:

- First, the maximum figure in the range of capital cost shown in Table C.1 is considered.
- Ten percent is added to this figure, as full design capacity utilization may not be reached in most projects.
- This figure is then increased by 30 percent (and rounded) because, in many cases, direct implementation may not take place and procurement may be done by a government or semi-government agency.

This provides a conservative estimate of the capital cost to pump and supply piped water. However, one aspect that has not been considered is that, in many villages, the piped water supply system may require a non-grid power supply. This would mean an investment in non-grid power systems. For a piped water supply scheme serving 200 households, a non-grid power supply based on diesel would require an additional investment of about Tk 500,000. Thus, the additional investment per household would be about Tk 2,500. This figure has been included to obtain a final estimate of the capital cost of piped water supply.

Similarly, to estimate O&M cost, maximum indicated range has been taken for a conservative cost estimate.

The capital and O&M cost estimates for a domestic piped water connection finally used for the study are shown in Table C.2.

Table C.2: Cost estimates for domestic piped water connection in rural Bangladesh

	Capital cost (Tk)	O&M cost (Tk/month)
Barisal (deep tubewell area)	12,500	65*
Chandpur (shallow water table area)	9,500	60
Chapai Nawabganj (low water table area)	9,500	60
Average of three areas	10,500	62

** The maximum of the O&M cost ranges given for the three areas are the same. However, the cost of pumping is likely to be higher in Barisal than that in the other two districts. The average cost is expected to be higher in Barisal compared to the other two districts by about Tk 5/month. The same difference is maintained in the cost estimates finally chosen.*

The cost estimates shown in Table C.2 can be applied to households opting for a domestic connection. The estimates for households opting for standposts should be lower as it is expected that five families would share a connection. How much lower the cost of standposts will be compared to private connections will depend on the quantity of water used. In some rural water supply projects in India the norms used are 40 lpcd for households using a shared connection and 70 lpcd for households using a domestic connection. It would not be wrong to use this ratio for the piped water supply project in rural Bangladesh. Based on these figures, the O&M cost for a household using a shared connection would be about 4/7 the O&M cost of a household using a domestic connection. The same proportion cannot be applied for capital cost. However, it may be noted that many important capital cost items, such as the size of the tank and the capacity of the pump, are related to the volume of water supplied. Therefore, the apportioning of these cost among the beneficiary households should be done according to the quantity of water consumed.

At the same time, it needs to be recognized that shared connections (standposts) would give rise to some cost saving with respect to the cost of the piped network. It seems reasonable, therefore, to assume that the capital cost of a standpost would be 50 percent of the capital cost of a domestic connection. The estimated cost of piped water supply for households using a shared connection/public standpost is shown in Table C.3.

Table C.3: Cost estimates for public standpost/shared piped water connection in rural Bangladesh

	Capital cost (Tk)	O&M cost (Tk/month)
Barisal (deep tubewell area)	6,250	37*
Chandpur (shallow water table area)	4,750	34
Chapai Nawabganj (low water table area)	4,750	34
Three areas combined	**5,250**	**35**

** The cost is slightly higher due to higher cost of pumping.*

Annex D

Estimation of the Value of Arsenic-Free Water by the Revealed Preference Approach

To estimate the value of arsenic-free water by the revealed preference approach, the following four components were valued and aggregated:

1. How many people have shifted their drinking water source as a result of arsenic contamination, and are now spending more time collecting drinking water? What is the value of the extra time being spent?
2. How many people have shifted from tubewells to surface water sources such as tanks and ponds, and are boiling water to remove bacteriological contamination? What is the value of time spent and fuel used in boiling water?
3. How many people had to install a new tubewell, or sink the existing tubewells deeper, because the earlier source of drinking water became contaminated with arsenic? What was the expenditure incurred?
4. How many households had to purchase arsenic reduction units and meet the cost of replacing the media in the filters? What is the expenditure incurred by households on this account?

The computations made to obtain an estimate of the value of arsenic-free water by the revealed preference approach are shown below. A component, that is, the cost associated with arsenic reduction units, has not been estimated because the equipment was distributed free and probably not much actual expenditure was incurred by households in operating and maintaining the equipment.

Cost of extra time spent to collect drinking water

The most important element of cost as a result of households changing their water source due to arsenic contamination was the extra time spent to collect drinking water. About 21 percent of the households in the sample area had changed their drinking water source in the previous three years due to arsenic contamination of the earlier source. The distance that these households now travel to collect water has increased from 84 feet to 556 feet. Consequently, the time spent has also increased from 9 minutes to 27 minutes a day. The valuation of the extra time was done on the basis of wage rate (taking into account the age-sex distribution of the person who generally collects drinking water for the family).

The average wage rate was about Tk 70 per day (based on the average wage rate of the three districts in the sample area and the wage rates in the busy and lean season). The wage rate for female workers was taken as Tk 50 per day. It is assumed that an adult will work for 300 days a year (eight hours a day). For children (below 16) and the elderly (above 55), the opportunity cost of time was taken as zero. The share of children and the elderly among the persons who have the responsibility of collecting drinking water for the family is shown in Table D.1. These proportions, along with the opportunity cost of time, were used to compute the value of extra time spent collecting drinking water. The value of the extra 18 minutes spent per day to collect drinking water was estimated as Tk 1.16, which works out to Tk 34.82 as the cost per month per household. To obtain the total cost of extra time spent by households for this purpose, the cost per household was multiplied by the number of households in the sample area that changed drinking water source due to arsenic (502 households). This works out to Tk 17,480 per month (Table D.2).

Table D.1: Age-sex distribution of the person who generally fetches water for the family (%)

Gender	Age (years)			Total
	Below 16	16-55	55+	
Male	6	7	1	14
Female	19	65	2	86
Total	**25**	**72**	**3**	**100**

Note: Figures have been rounded.

Cost of boiling water drawn from tanks/ponds

For households that had shifted their water sources to tanks/ponds, the cost of boiling of water was computed by taking into account the time spent in boiling water and the cost of fuel. Based on the information collected in the survey, the time spent in boiling was taken as 30 minutes per day and the cost of fuel Tk 150 per month (most households used either wood, or crop residue to boil water). The opportunity cost of time spent was based on the female wage rate, that is, Tk 50 per day.

The cost estimates are presented in Table D.3. Out of the 4,230 households covered in the sample area, 49 households (about 2 percent of the total households in the sample area) had shifted to tanks/ponds due to arsenic contamination and were boiling tank/pond water to make it suitable for drinking. The value of time spent for this purpose comes to Tk 3,773 per month and the cost of fuel used was found to be Tk 7,350 per month. The total cost incurred on boiling was, therefore, Tk 11,123.

Cost of investments in new tubewells

It is assumed that only one-fourth of the new tubewells that were installed (or drilled to a lower depth) by the households covered in the survey was due to arsenic contamination. Based on information gathered on the cost of tubewell installation, the expenditure per unit has been taken as Tk 2,500.

The estimated cost of investing in tubewells due to arsenic contamination is shown in Table D.4. Out of

Table D.2: Computation of the value of extra time spent to collect drinking water among households that had shifted their source due to arsenic contamination

Indicator	Value
Total households (in the sample area)	2,430
Number of households that changed their drinking water source due to arsenic	502
Time spent collecting water before change	9 minutes/day
Time spent after change	27 minutes/day
Difference	18 minutes/day
Value of extra time spent per household per day	Tk 1.16
Value of extra time spent per household per month	Tk 34.82
Total value of extra time spent to collect water by households that had changed their drinking water source due to arsenic contamination (Tk per month)	17,480

Table D.3: Value of time spent and expenditure incurred to boil water among households that had shifted their drinking water source to ponds/tanks due to arsenic contamination

Indicator	Value
Number of households that had shifted to other sources such as ponds/tanks	61
Of these, the number of households that were boiling water	49
Time spent per day boiling water	30 minutes/day
Value of time per household	Tk 77/month
Total value of time for boiling water among households that had shifted to tanks/ponds (Tk/month)	3,773
Cost of fuel used for boiling per household per month	Tk 150
Total cost incurred on fuel for boiling (Tk/month)	7,350
Value of time spent and cost incurred on fuel for boiling (Tk/month)	11,123

Table D.4: Computation of the cost of investments in a new tubewell installed due to arsenic contamination

Indicator	Value
Number of households that had installed a new tubewell in the last five years	298
Number of households that invested in a new tubewell due to arsenic contamination	75 (assumed to be 25%)
Average amount spent per tubewell	Tk 2,500
Total amount spent to sink a tubewell	187,500
Monthly interest cost (at the rate of 12% per annum) (Tk/month)	1,875

the 2,430 households covered in the sample area, 298 households reported that they had invested in new tubewells in the previous five years, at a total investment of Tk 187,500. It is assumed that 25 percent (75 households) invested in a new tubewell due to arsenic contamination. The cost of monthly interest would be Tk 1,875, assuming an annual interest rate of 12 percent.

The total sum of cost under the three heads (cost of extra time spent to collect water, cost of time spent, and fuel used for boiling tank/pond water, and cost of investment in new tubewells) was Tk 30,478 per month. Dividing this by the total number of households covered in the sample area, the cost per household was Tk 12.5 per month.

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The Water and Sanitation Program is an international partnership to help the poor gain sustained access to improved water supply and sanitation services. The Program's main funding partners are the governments of Australia, Belgium, Canada, Denmark, Germany, Italy, Japan, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom; the United Nations Development Programme and The World Bank.

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