Rural communities' preferences for arsenic mitigation options in Bangladesh

Junaid Ahmad, Bishwanath Goldar and Smita Misra

ABSTRACT

In the context of arsenic contamination of groundwater in Bangladesh, this paper analyses rural people's preferences for arsenic-free drinking water options. A particular focus is on rural households' willingness to pay for piped water supply which can provide a sustainable solution to the arsenic problem, and how the preference for piped water supply compares with that for various other household/community-based arsenic mitigation technologies. The analysis is based on data collected in a survey of over 2700 households in rural Bangladesh. Six arsenic mitigation technologies were selected for the study: three-*kolshi* (pitcher) method, activated alumina method (household-based and community-based), dugwell, pond sand filter and deep tubewell (handpump). The survey results indicate that, after taking into consideration the initial and recurring costs, convenience, associated risks and the advantages and disadvantages of each selected technology, the preference of the rural people is overwhelmingly in favor of deep tubewells, followed by the three-*kolshi* method. The analysis reveals a strong demand for piped water in both arsenic-affected and arsenic-free rural areas, and scope of adequate cost recovery. Between piped water and other arsenic mitigation technologies, the preference of the rural people is found to be predominantly in favor of the former.

Key words | arsenic contamination, deep tubewell, mitigation options, people's preferences, piped water, rural Bangladesh

Junaid Ahmad
The World Bank, 1818 H. St. NW,
Washington DC, 20433,
USA

Smita Misra
World Bank 70 Lodi Estate,
New Delhi 110003,
India

Bishwanath Goldar (corresponding author)
Institute of Economic Growth,
University of Delhi Enclave,
North Campus, Delhi 110007,
India
E-mail: *bng@iegindia.org*,
goldarbng@rediffmail.com

INTRODUCTION

As a result of the arsenic contamination of groundwater in most areas of the country[1], Bangladesh is currently facing a long-term health epidemic of cancers and other fatal diseases related to arsenic exposure. 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. A survey of randomly selected 3780 Bangladeshi households conducted by the National Centre for Epidemiology and Population Health of Canberra, Australia has put the prevalence rate of dermatological manifestations of arsenic poisoning at 2.8 per 1000 population (Ahmed & Ahmed 2002). Extrapolations done by BUET (Bangladesh University of Engineering and Technology) using USEPA models suggest that some 375 000 people of Bangladesh may eventually develop various arsenic related cancers (Ahmed & Ahmed 2002, p. 61).

To find solutions to the arsenic problem in Bangladesh, numerous bilateral and international agencies, the government and NGOs (non-government organizations) are involved in arsenic research, testing and mitigation activities. However, solutions so far have tended to focus mainly on issues on the 'supply side'. Research has been conducted on the engineering aspects of various arsenic mitigation technologies

[1]Arsenic contamination of the groundwater has been detected in 59 of the 64 districts, and 249 of the nation's 463 sub-districts. Estimates suggest that about a quarter of the 6–8 million tubewells in Bangladesh may contain arsenic levels of more than 50 ppb (parts per billion) 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 (see Ahmed & Ahmed 2002; British Geological Society & Mott MacDonald, 2000; Caldwell *et al.*, 2003).

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to assess whether the technology is effective (see, for example, BAMWSP, DFID & WaterAid Bangladesh 2001; BRAC 2000) and 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 share the costs of more robust and sustainable[2] solutions, such as rural piped water supply.

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 would require greater public intervention to regulate and manage these schemes. These factors may have contributed to the limited appeal of this technology. In contrast, it is believed that tubewells do not need to be managed by public institutions as households and communities can access this technology directly from the market[3]. Thus, preserving the use of the tubewell technology, if possible, has become an implicit if not explicit goal of the approaches currently being advocated to address the drinking water crisis in Bangladesh.

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

An important question that arises here is: are rural people strongly inclined towards using arsenic removal equipment for taking care of the arsenic problem? It goes without saying that while arsenic removal technologies clearly provide practical short-term solutions, particularly in areas where arsenic contamination is high, the effectiveness of these technologies in the long run depends critically on the ability of local communities to accept, operate and maintain the technologies/equipment[4]. It may be pointed out in this context that, although a number of household arsenic removal units have been distributed, only a few are actually being used. It has been suggested that, although various arsenic removal technologies are being field tested by BAMWSP (Bangladesh Arsenic Mitigation Water Supply Project), "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, p. 7).

FIELD STUDY

The fact that household preferences among arsenic mitigation technologies have not received due attention in the past research on arsenic problems in Bangladesh provided motivation for undertaking a major study on this aspect in

[2]Sutherland *et al.* (2001) note that the sustainability of arsenic mitigation technologies is not just a function of the inherent robustness of the technology and of the treatment process used, but a function also of the infrastructure and support services available to the users of the technologies. If a technology has very little requirement of spare parts or reagents, then it may be sustainable. If a technology needs a constant supply of reagents and spare parts, this need not make it unsustainable, so long as the support services for the technologies are local and effective. Drawing on this observation of Sutherland and associates, it seems reasonable to argue that in regard to sustainability, piped water supply has an edge over arsenic removal technologies, because piped water supply schemes can easily procure support services, whereas setting up a system of support services for arsenic removal technologies may be difficult.

[3]There is a presumption by many donors that network systems which have a monopoly element need public regulation and that in countries that have weak governments, public regulation usually leads to public service provision, i.e. the departments of public and health engineering (PHEDs) will argue that they are best positioned to deliver the network systems. In this political context, the donors suggest that it is best to use tubewells that are private goods delivered through a competitive market. No PHED can suggest that they are better able to deliver goods that the market can deliver directly to households. But, this does not mean that no public regulation is required. While the market can deliver tubewells, public regulation is still needed; not of the delivery process but of the water quality. In fact, the arsenic contamination was not picked up earlier because it was assumed that having privatized the delivery process – tubewells to households in a very competitive market of tubewell producers – there was no need for public oversight. What was forgotten is that water quality monitoring of the water source required public intervention even though the delivery process did not.

[4]As all arsenic removal technologies generate some arsenic-rich waste, the safe disposal of toxic sludge from these treatment units is another crucial issue.

the context of rural Bangladesh. The study mainly focused on rural people's preferences among various proposed solutions to the arsenic problem, and their willingness to pay for piped water supply (Annex A describes the relevant sections of the questionnaire). Other aspects covered in the study are rural people's perception of the arsenic problem and the steps they are taking after discovering arsenic contamination in their drinking/cooking water source. By its very nature, the study had to be based on primary data collected from households in a survey.

Different arsenic mitigation technologies, including accessing alternate arsenic-free sources, were discussed with the respondents, the advantages and disadvantages of the technologies explained, and the capital cost and recurring costs of the technologies specified. After providing this information, the respondents were then asked to indicate their preferences among arsenic mitigation options. This study used the contingent valuation methodology[5] to assess household preferences and willingness to pay for piped water supply.

The field survey was conducted between October–December 2001. Households were divided into sample and control areas. The sample area (2430 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)[6]. These areas are representative of the available water resources, current levels of water consumption and related convenience aspects in Bangladesh. 300 households were covered in the arsenic-free control areas–150 from Bolarhat *thana* in Chapai Nawabganj district and 150 from Commilla Sadar *thana* in Commilla district. Care was taken to ensure that the sample was representative and quality data collected. To get a representative sample, households were selected by the stratified random sampling method.

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, and biases commonly associated with contingent valuation studies are minimized, 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. 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.

Split sampling

In the study, a closed-ended question format[7] was used for eliciting rural households' willingness to pay for piped water (see Annex A). As is common among studies using the closed-ended question format, this question format was coupled with split sampling. The total sample for the arsenic-affected (sample) area was divided into five sub-samples. Similarly, the total sample for the arsenic-free (control) area was divided into five sub-samples. Five different charges for public standposts and domestic connections were quoted (during the interview) in five different sub-samples (explained in Ahmad *et al.* (2005)), and then the respondent was asked to make a choice between a public standpost or a domestic connection. A third choice was to reject both and to continue to depend on present sources of water.

The quoted piped water charges varied considerably across the different sub-samples. The quoted monthly payment towards O&M (operation and maintenance) for a public standpost ranged from Taka (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

[5]For discussion on the contingent valuation methodology, see Mitchell & Carson (1989), Bjornstad & Khan (1996) and Garrod & Willis (1999), among others. There have been a large number of studies in which the contingent valuation methodology has been applied to assess demand for improved water supply in rural areas of developing countries (see, for example, Briscoe *et al.* 1990; Whittington *et al.* 1990; Singh *et al.* 1993). A number of studies have applied the contingent valuation methodology to the value of groundwater quality (see, for example, Bergstrom *et al.* 2001). This is the first application of the contingent valuation methodology in the context of the arsenic contamination of groundwater.

[6]Within each district, three *thanas* severely affected by arsenic were selected for the study (a *thana* is an administrative unit below the sub-districts). Five villages were randomly selected in each identified *thana* and 53–55 households randomly selected in each selected village.

[7]In the open-ended elicitation method, the respondent is asked to state the highest sum he/she is willing to pay. In the closed-ended referendum type elicitation method, the respondent is asked whether or not he/she would be willing to pay a particular amount for the good being valued. The advantage of a closed-ended question format is that it is convenient for the respondent to weigh the suggested price options, especially since the good is not available in the market. A more compelling reason for using the closed-ended question format is that it is better able to control for strategic bias in the responses.

Tk 30 per month in the first sub-sample to Tk 100 per month in the fifth sub-sample. Contributions towards initial capital cost quoted during the interview ranged from Tk 200 in the first sub-sample to Tk 1000 in the fifth sub-sample for a public standpost, and Tk 500 to Tk 3000 (first to fifth sub-sample) for a domestic connection[8].

In the first sub-sample, the charges quoted were lower than the estimated costs of piped water supply. In the fifth sub-sample, the charges quoted were higher than the estimated costs. The charges quoted in the other sub-samples fell in-between the two. The responses obtained with regard to preference for a standpost, a domestic connection or neither provided the basic data which were analyzed econometrically (with the help of a multinomial logit model) to estimate the willingness to pay for piped water supply[9].

THE ARSENIC PROBLEM: HOUSEHOLD AWARENESS, EXPERIENCE AND COPING STRATEGIES

Survey data reveal that most of the respondents (87% in the sample area and 53% in the control area) had some knowledge of the arsenic problem. Their sources of information varied from development agencies working in rural areas (NGOs/government/other agencies), other residents in 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, about half the respondents had some idea of the symptoms of arsenicosis, but only 35% 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%. Thus, while the majority were aware of the arsenic problem, awareness levels of 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.

Roughly 58% of the households in the sample area reported that the tubewell owned by or accessible to them had been tested for arsenic. In the control area, less than 1% 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 results reflect a marked inter-district variation in the level of contamination. Of the tested tubewells in Chandpur (reported by households in the survey), over 90% had been found to be arsenic-contaminated. The proportion was much lower in the arsenic-affected areas of Chapai Nawabganj (23%) and Barisal (41%). In the sample area as a whole, 61% of the tested tubewells had been found to be contaminated with arsenic.

About 35% of the households in the sample area had directly encountered the problem of arsenic contamination. About 59% of these households (approximately 20% of the total sample) had shifted to alternate safe sources, mainly public deep tubewells. However, the remaining 41% (about 15% of the total sample) were continuing to use tubewells that were known to be arsenic contaminated primarily because there was no suitable alternate source (as reported by the respondents). One percent of the respondents said that they had not shifted to a safer source because they were unconcerned about the consequences of arsenic poisoning.

As noted above, about 20% of the households covered in the survey had shifted to alternate safe sources for drinking water because of arsenic contamination; for the majority this meant a switch from domestic to public tubewells. This made it necessary for such households to walk long distances to collect drinking water. Taking together all the households who had shifted their drinking water source due to arsenic contamination during three years prior to the survey, the average distance travelled by

[8]The capital cost contributions quoted in the interview implicitly assumed that the beneficiary households would pay at least 10% of the capital cost of piped water supply schemes.

[9]See Annex B. The methodology used in this study is similar to that used by Pattanayak *et al.* (2002) for a study of the willingness to pay for piped water supply in Kathmandu Valley, Nepal. They have used a closed-ended question format with split-sampling and applied a multinomial logit model to derive the estimates of willingness to pay.

them for collection of drinking water went up from 84 feet to 556 feet. The average time spent increased from 9 min to 27 min, requiring the households to spend on average an additional 18 min every day for the collection of drinking water. About 2.5% of the surveyed households in arsenic-affected areas (or about one-tenth of the households who had changed their drinking water source due to arsenic contamination) were using pond or tank water for drinking. Most of them were boiling pond/tank water to make it suitable for drinking.

HOUSEHOLD PREFERENCES AMONG ARSENIC MITIGATION TECHNOLOGIES

Based on earlier studies (BRAC 2000; BAMWSP, DFID & Water Aid Bangladesh 2001), the following six technologies were selected for the study: (i) three-*kolshi* (pitcher) method, (ii) activated alumina method (household-based), (iii) activated alumina method (community-based), (iv) dugwell, (v) pond sand filter and (vi) deep tubewell (handpump). These technologies are representative of arsenic reduction units (such as the three-*kolshi* method), as well as technologies which make use of alternate safe water sources (such as pond sand filter or deep tubewell).

The survey data reveal that, based on considerations of convenience (disregarding capital and recurring costs), the dominant preference was for community-based technologies. About 72% of respondents preferred a community-based technology while 28% opted for household-based technology[10].

On the choice between a technology that purifies arsenic-contaminated tubewell water (e.g. three-*kolshi* method) versus a technology that makes use of an alternate source of safe water (e.g. deep tubewell), based on a consideration of the risks associated with each technology, the preference was to a certain extent in favor of the latter. About 56% of the respondents preferred alternate safe water sources to a technology that purifies arsenic-contaminated tubewell water.

When respondents were asked to choose from the six technologies after taking into consideration the capital and recurring costs, convenience, associated risks and the advantages and disadvantages of each technology, about 76% 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 1331 out of 1854 respondents (72%) (see Table 1). The three-*kolshi* method was the second most preferred option, with 291 (16%) ranking it first and another 490 (26%) ranking it second. Dugwells and pond sand filters were given low preference in the ranking of technologies.

Deep tubewells were the preferred method both among those who had used or were currently using them as well as among households that had not used any of the six selected technologies. 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 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* technology 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 2). In both categories of households, the dominant preference was for deep tubewells, followed by the 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.

[10]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, p 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 since this involves individual risk. Community-based technologies involving community efforts and shared risks would have greater appeal.

Table 1 | Ranks given by the households to the six selected arsenic mitigation technologies

Technology	No. of households giving first choice	No. of households giving second choice
Three-*kolshi* (pitcher) method	291 (15.8)	490 (26.6)
Activated alumina (household-based)	88 (4.8)	185 (10.0)
Activated alumina (community-based)	61 (3.3)	140 (7.6)
Dugwell	44 (2.4)	341 (18.5)
Pond sand filter	29 (1.6)	231 (12.5)
Deep tube-well (hand pump)	1331 (72.2)	234 (12.7)

Note: Figs. in brackets are percentages (out of the 1854 households that reported their preferences in terms of ranking the technologies).

DEMAND FOR PIPED WATER

The survey results indicate that respondents perceived a number of advantages in a piped water supply system. In the sample area, about 60% 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% felt that it would be good for health and 48% felt that it would be convenient[11]. The perceived advantages of piped water supply systems in the control area were largely similar. About 85% felt that a piped water supply system would provide clean water, 46% felt that it would be good for health and 37% felt that it would be convenient. A related question regarding the advantages of having a domestic piped water connection was asked. Not surprisingly, convenience was perceived to be the main advantage by more than 70% 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.

A multinomial logit model was applied to the survey data to analyze econometrically household preferences for piped water supply (see Figure 1) and derive estimates of average willingness to pay for such a service in the sample and control areas, and among poor and non-poor households.

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[12]. The results also indicate that the higher the awareness and concern for arsenic contamination (measured by an arsenic score constructed from responses to nine arsenic-related questions, applying principal component analysis), 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 increases 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.

[11]The question asked in the survey was: "In your opinion, what is the advantage of piped water supply?" Five possible answers were listed: (1) no advantage at all, (2) clean water, (3) better for health, (4) more convenient, and (5) other advantages. The replies given by the respondents were recorded, making allowances for multiple responses. In a number of cases, the respondents went beyond the pre-selected list. Thus, responses included: "We can get arsenic-free water/we can get safe water/we can get germ-free water", "we shall get water good for drinking" and "we can get rid of disease".

[12]The parameter estimates of the multinomial logit model are available in Ahmad *et al.* (2005), and hence not presented here.

Table 2 | 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 respondents who ranked the technology first while the figure in brackets indicates the number of respondents who ranked the technology second.

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 arsenic-affected sample area, the estimated average willingness to pay for the initial capital cost was Tk 960 for standposts and Tk 1787 for domestic connections. The monthly estimated average willingness to pay towards recurring costs was Tk 51 and Tk 87 respectively (see Table 3).

The estimated average willingness to pay of poor households (monthly household income less than Tk 3600) was Tk 44 per month, plus an initial payment of Tk 838 for public standposts and Tk 68 per month plus an initial payment of Tk 1401 for a domestic connection. As expected, the estimated willingness to pay for non-poor households was significantly higher (Table 3). The non-poor households were, on average, willing to pay Tk 59 per month for a standpost and Tk 112 per month for a domestic connection. They were willing to contribute Tk 1119 towards the capital cost of a standpost and Tk 2318 towards the capital cost of a domestic connection.

In the sample area, the average willingness to pay of households more than covers the actual O&M costs of piped water supply (based on cost estimates of on-going schemes in Bangladesh). The average willingness to pay for standposts was 46% higher than the actual O&M costs while for domestic connections the willingness to pay was 40% higher (Table 4). Among poor households, the average willingness to pay for standposts exceeded the O&M costs by more than 26% and exceeded the actual cost by 10% for a domestic connection.

With regard to willingness to share the capital cost of piped water supply projects, the estimates of average willingness to pay for both poor and non-poor households of the sample area were more than 10% of the actual capital costs. The average for all households was 18% of the capital costs for standposts and 17% of the capital costs for a domestic connection. While poor households on average are willing to pay 16% of the capital cost of standposts and 13% of the capital cost of a domestic piped water connection, non-poor households are willing to pay 21% of the capital cost of standposts and 22% of the capital cost of a domestic connection.

In rural water supply projects in developing countries, the share of capital cost to be borne by the households is often set at 10% or so. India, for example, has implemented the largest government financed rural drinking water program under the Rajiv Gandhi National Drinking Water Program, targeting about 70 million people across 26 states, in which rural households are expected to cover 10% of the

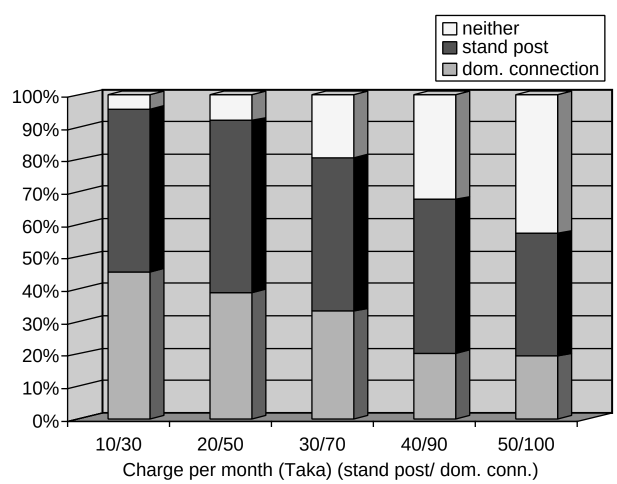

Figure 1 | Household choices regarding piped water supply in arsenic-affected areas.

Table 3 | Estimated average willingness to pay

	Public standpost		Domestic connection	
	O&M (Tk/month)	Capital cost (Tk) (one time payment)	O&M (Tk/month)	Capital cost (Tk) (one time payment)
Arsenic-affected (sample) area				
Poor	44 (1.9)	838 (3.0)	68 (2.9)	1401 (5.0)
Non poor	59 (0.8)	1119 (1.2)	112 (1.5)	2318 (2.6)
All	51 (1.1)	960 (1.7)	87 (1.9)	1787 (3.2)
Arsenic-free (control) area				
Poor	39 (1.7)	785 (2.8)	67 (2.9)	1310 (4.7)
Non poor	56 (0.7)	1135 (1.3)	122 (1.6)	2385 (2.6)
All	46 (1.0)	937 (1.7)	91 (2.0)	1775 (3.2)

Source: estimated from survey data.
Note: Figures in brackets are willingness to pay as percent of income. For capital cost, annual income is taken.
One Bangladesh Taka (Tk) = approximately 0.017 US$ (August 2002).

Table 4 | Ratio of willingness to pay (WTP) to estimated actual supply cost (percent)

	Public standpost		Domestic connection	
	O&M	Capital cost	O&M	Capital cost
Arsenic-affected (sample) area				
Poor	126	16	110	13
Non poor	169	21	181	22
All	146	18	140	17
Arsenic-free (control) area				
Poor	115	17	112	14
Non poor	165	24	203	25
All	135	20	152	19

Note: For the sample area, the estimated O&M costs are Tk 35 per month for a standpost and Tk 62 per month for a domestic connection. The estimated capital costs are Tk 10 500 per family for a domestic connection and Tk 5250 per family for a standpost. These cost estimates of piped water supply are based on cost information in respect of some on-going piped water supply projects in Bangladesh. For the control area, the cost estimates are lower, as this area does not include the coastal districts where the costs of piped water are relatively higher.

capital costs (and the full amount of the O&M costs). The willingness to pay estimates indicate that the rural households of arsenic-affected areas of Bangladesh would in general be willing to pay more than this percentage of the capital costs and O&M costs of piped water supply projects. Indeed, the estimates of willingness to pay point to the possibility of recovering much more than 10% of the capital costs from the rural households.

The estimated willingness to pay for piped water in the arsenic-free (control) area was similar to that for the sample area (a little lower in the case of public standposts) (see Tables 3 and 4). On average, the willingness to pay in the control area exceeded the actual O&M cost of piped water supply and was more than 10% of the capital cost of both public standposts and domestic connections, among both poor and non-poor households. Evidently, a strong demand for piped water supply exists not only in the arsenic-affected areas but also in the areas free from the arsenic problem.

Affordability of piped water systems

On average, rural households in the sample area were willing to pay about 1.1% of their monthly income towards

O&M charges for public standposts and about 1.9% of their monthly income towards O&M charges for a domestic piped water connection (see Table 3). With regard to willingness to pay for capital cost, on average, households in the sample area were willing to pay about 1.7% of their annual income as a one-time payment for a public standpost, and about 3.2% of their annual income for a domestic connection.

Average willingness to pay as a percentage of income in the control area was very close to that in the sample area. For instance, households in the control area are, on average, willing to pay 1.0% of their monthly income towards O&M charges for public standposts and 2.0% of their monthly income towards O&M charages for a domestic connection.

The finding that the average willingness to pay is a very small percentage of the mean household income and is adequate to cover the recurring cost of piped water supply and the commonly stipulated share in the capital cost of such schemes indicates that piped water supply systems may well be affordable in many rural areas of Bangladesh.

The finding that the average WTP in the arsenic-affected area was quite similar to that in the arsenic-free area in absolute values, as a percentage of household income, and as a ratio to the actual supply cost is a bit surprising because concerns for arsenic should make households in the arsenic-affected area more willing to pay for piped water. Perhaps a more appropriate comparison is between the mean WTP in the arsenic-free area and that of those households in the arsenic-affected area who are relatively more aware of and concerned about the arsenic problem. When such a comparison is made, the average WTP is found to be higher in the arsenic-affected areas, but the difference is not large[13]. It seems therefore that the demand for piped water in the arsenic-affected areas is not driven in a major way by considerations of arsenic contamination[14]. Rather, considerations of convenience appear to be a far more important factor driving the demand for piped water in both arsenic-affected and arsenic-free areas. This does not, however, limit the potentiality of piped water supply systems in providing a sustainable solution to the arsenic problem. For, whatever the driving force, the households in the arsenic-affected area are very much interested in piped water supply systems and are willing to pay for them, and this would take care of the problem of arsenic contamination.

PIPED WATER SYSTEMS VERSUS ARSENIC MITIGATION TECHNOLOGIES: WHAT DO HOUSEHOLDS PREFER?

In the survey, 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 to this question clearly indicate that taking into account the costs and other aspects, the preference of the respondents was predominantly for piped water supply (about 89%) rather than other arsenic mitigation technologies (see Figure 2). Even when the respondents were asked to make a comparison with the assumption that there would be an 80% capital subsidy on arsenic mitigation technologies, the proportion of respondents preferring piped water supply remained high (about 78%).

The main reasons given by respondents for choosing piped water supply system over other arsenic mitigation technologies are convenience and getting water that is free from arsenic as well as bacteriological contamination. Of the 2023 respondents who chose piped water over other arsenic mitigation technologies, 69% mentioned the convenience of piped water as the main reason or one of the reasons for preferring this option.

There was a strong preference for piped water over arsenic mitigation technologies (90%) among respondents who had no experience of the technologies. However, the preference for piped water was almost equally strong among households who had used or were currently using arsenic mitigation technologies. About 90% of the households who had used the three-*kolshi* method or activated alumina technology, and about 80% of the households who

[13]The difference is about Rs 9 per month for public standposts and about Rs 11 per month for domestic connections. The difference is found to be statistically significant in both cases. But it is only about 0.2% of the average income of households. It may be pointed out in this context that half of the control area households reside in relatively more developed areas than the sample area households, and the problem of high iron content in water is relatively higher in the control area (both factors tend to raise demand for piped water). If these two differences between sample and control areas are controlled for, the gap between willingness to pay for piped water between sample and control areas would be higher. See Ahmad *et al.* (2005) for further discussion on this point.

[14]This is consistent with the finding of the survey that there is lack of awareness of the serious health effects of consuming arsenic-contaminated water in the arsenic-affected areas, which is suggestive of a low risk perception of arsenicosis.

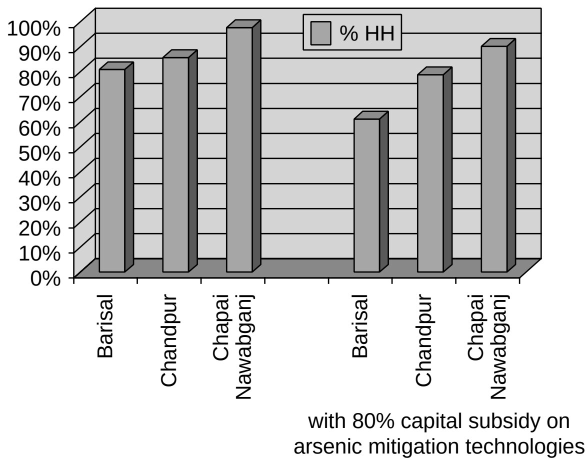

Figure 2 | Household preference for piped water over arsenic mitigation technologies.

had used deep tubewells, expressed preference for piped water over their most preferred arsenic mitigation technology.

THE ROAD AHEAD

The study offers important insights for policy makers on the broad parameters that may provide a framework for addressing the arsenic crisis. The key messages relating to the technological options for arsenic mitigation are given below:

- Unless household level filtering systems become affordable and convenient to use, and preferably easy to link to shallow tubewells, these may not meet with much success in solving the drinking water crisis in Bangladesh. The convenience of shallow tubewells will make it difficult to promote alternative solutions such as ponds and dugwells. Any alternative to tubewells has to provide not only access to safe water but the convenience of the tubewell technology as well.
- There is a strongly voiced preference for piped water systems. The density of rural settlements in Bangladesh and the growth of rural incomes in the last two decades may have improved the affordability of piped network systems. In terms of arsenic contamination, piped water systems with their central treatment facility are advantageous over the household level technology because the system can be managed and monitored at a single point. Furthermore, the treatment technology can be easily improved/altered centrally as and when better alternatives become available. An added advantage is that a central filtration system allows for the treatment of pathogenic contamination of surface water enabling perhaps a return to surface water – which is free of arsenic contamination – for rural communities but with the use of a more convenient technology.
- The option of rural piped water systems has, however, been underplayed in Bangladesh, possibly due to the failure to sustain such systems in other South Asian countries. A possible reason for the limited success of piped water systems in South Asia could be the organizational structures through which these systems have been implemented rather than issues of technology and affordability. 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 through alternative organizations that are responsive to rural consumers. In particular, it will be important to assess the potential of delivering network systems through independent (non-public) service providers.
- The estimates of willingness-to-pay obtained in this study are indicative of the possibility of introducing a demand-driven program to expand rural drinking water similar to the one currently being applied in India and other parts of the world with the potential of perhaps even having a higher contribution from households. This hypothesis can only be tested by actively pursuing piped water pilots on the ground to engage in 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.
- But, even as the choice for piped water is very high, it will be important not to offer households a one-point solution. There is still a statistically significant number of households that will prefer other technologies. While the areas sampled in this study do reflect broadly the socioeconomic profile of rural Bangladesh, there are rural areas in the country where the density and income

levels of villages may warrant a household technology. Keeping open the option of choice is very important, especially in a context where technologies and technology costs may evolve very rapidly.

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DISCLAIMER

The findings of this study are the personal views of the authors and do not reflect any official position of the World Bank group or its affiliates or any other organization to which the authors belong.

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APPENDIX A: QUESTIONNAIRE USED FOR THE SURVEY – SECTIONS DEALING WITH HOUSEHOLD PREFERENCES AND WILLINGNESS TO PAY

(1) Preference for arsenic mitigation technologies other than piped water

This section of the questionnaire, on arsenic mitigation technologies other than piped water, began with the following introductory remarks (text reproduced).

"Currently a number of arsenic mitigation technologies are being tried and tested by various agencies. The major technological options available will be explained to you, including the volume of water you can get in a day, capital cost of these technologies, operation and maintenance costs and their effectiveness. This will be followed by questions on whether you would like to use these technologies. We want to know your preference regarding the technologies.

"Please consider the alternate technological options. Evaluate the merits and limitations, as well as the costs of these technologies carefully, because your assessment will help in developing right technologies for tackling the arsenic problem."

Specially designed cards for the six selected technologies were then shown to the respondent. These cards for the six technologies, shown one by one, gave basic information on the different technologies selected for the study (whether the technology is household-based or community-based, whether the technology permits the household to use their current tubewell water or will it require them to shift to an alternate source, cost of each technology, one-time capital cost and annual O&M cost, and the advantages and disadvantages of each technology) and explained how much arsenic-free "safe" water could be obtained in a day.

Next, the respondents were asked to make a choice between household-based and community-based technologies (on grounds of convenience) and between technologies that permit use of existing tubewell water and those that involve shifting to an alternate source of water (on considerations of risks). The text is reproduced.

"Now we would like you to specially think of your ***convenience*** in using the alternate technologies mentioned to you. Note that if you use household based technologies, you will get safe water within your household. However, you will be responsible for its operation and maintenance as well as safe disposal of sludge. If you use community-based technologies, you will have to fetch water from outside, but at the same time you will be saved the burden of operation and maintenance and disposal of sludge.

"Would you like to use household based technologies or community based technologies? While answering this question disregard the costs of different technologies and consider only or mainly your convenience.

☐ Household based technology 1
☐ Community based technology 2
☐ Indifferent between them 3"

"Next, we would like you to think of the ***risks*** associated with these technologies. If you use technologies which treat tubewell water, perfect maintenance of equipment is very necessary, otherwise the equipment may, after some use, fail to reduce arsenic to the desired levels. In addition, water quality has to be monitored from time to time to ensure 'safe' supply of drinking water. But, the technologies based on alternate water source such as pond or dug well have no such risks. However, there could be problems of taste/bacteriological contamination with technologies which use alternate water sources.

"Considering all such factors, would you prefer a technology treating tubewell water or a technology using alternate source of water?

☐ Tube well water based technology 1
☐ Alternate water source based technology 2
☐ Indifferent between them 3"

Having answered these two questions relating to convenience and risks associated with the technologies, the respondent was asked to consider the costs associated with the technologies (information provided). A card was shown to the respondent giving summary information on all the six technologies and the following question was asked (text reproduced).

"Consider the convenience, risks, costs and quantity of water available from these technologies. Would you like to use any of the listed technologies? Needless to say that to use them you will have to pay for them, or in the case of community

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based technologies, you will have to share the costs with others in the village. While answering this question keep in mind the health risks of consuming arsenic contaminated water and the high cost of treatment of arsenicosis. Consider also the fact that your family income is limited. If you spend on arsenic mitigation technologies, you will have to forego consumption of some other goods or services.

☐ Yes, I would like to use 1

☐ No, I would not like to use 2"

The respondents who expressed willingness to pay and use one or more of the technologies were then asked to indicate their most preferred and second most preferred technology[15]. The text of the question is reproduced.

"We want you to consider the listed technologies. Then, among the ones you would like to use, rank the two best technologies, the most preferred and the next most preferred. In ranking the technologies, consider carefully the health risk of arsenic contamination, your income, cost of the technology, to what extent these are able to reduce arsenic concentration in water to safe limits, whether the water obtained from these technologies are good in taste and free from bacteriological contamination, etc."

(2) Preferences for piped water

Piped water as a possible arsenic mitigation option was introduced after completing the section on the preferences for other arsenic mitigation technologies. The section on piped water began with the following remarks (text reproduced).

"So far we have talked of arsenic mitigation technologies. As an alternative, piped water supply could be a long-run solution to the arsenic problem. Please answer the following questions carefully because it will help us in evaluating your preferences for piped water supply schemes and make suitable recommendations to the government.

"The alternate piped water supply scheme could be based on surface water, and if that is not available it could be based on 'safe' ground water (given the availability of safe water sources in your village). In both cases, the scheme will provide water free from arsenic or bacteriological contamination. The inhabitants of the village can get private connection of piped water in the house or get piped water from public standposts. In this context, let me ask you some questions on the benefits of piped water supply."

Having asked the respondent questions about the perceived advantages of piped supply and the favoured agency for implementation and management of such schemes in the village, he/she was asked the following question 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, washing, etc. 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 costs 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

[15]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% or 50% (capital cost). Those who showed interest in using the technology with capital subsidy were then asked to indicate their most preferred and second most preferred technology.

[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 costs per month for the domestic connection option.
[*Enumerator: please fill the allotted O&M cost from the numbers given.*]

(e) Given the above costs 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, health, etc]

☐ 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 subsamples (see Ahmad *et al.* 2005)".

APPENDIX B: ECONOMETRIC METHODOLOGY[16]

For studying rural households' preferences for piped water econometrically, the multinomial logit model has been applied. The model explains the choice made by an individual or a household among available alternatives (say m alternatives). The model may be written as

$$\text{Prob}(Y_i = k) = \frac{e^{\beta_k X_i}}{\sum_j e^{\beta_j X_i}}. \qquad (1)$$

The above expression gives the probability of kth item being chosen by individual i. 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. Y_i is a random variable indicating the choice made.

A linear structure is assumed for the utility function underlying the model. Thus, the utility function of the ith respondent/household for the kth item may be written as

$$U_{ki} = \beta_k' X_i + \varepsilon_{ki}. \qquad (2)$$

It is assumed further that the disturbance terms ε_{ki} are independent and identically distributed with Weibull distribution.

The estimation of the model is done by the maximum likelihood method. A convenient normalization that is done is to assume that $\beta_0 = 0$, i.e. the parameter vector for the baseline choice is taken to be zero.

To apply the model described above, a set of explanatory variables have been used, including household income, and quoted monthly payment for a public standpost (capital and O&M combined) and a domestic connection (capital and O&M combined). The dependent variable is the choice made by the respondent: public standpost (1), domestic piped water connection (2) and neither of them (0).

Since awareness and concern about the arsenic problem should be an important factor influencing people's demand for piped water supply in the sample area, an index of awareness and concern about arsenic has also been included among the explanatory variables of the multinomial logit model. This is given by an arsenic score formed with the help of Principal Component analysis applied to nine arsenic-related variables representing responses to the nine arsenic-related questions (for details, see Ahmad *et al.* (2005)).

The estimated utility functions obtained from the estimation of the multinomial logit model may be written as

$$\text{conventional source (baseline utility)}: \quad U_0 = w_0(q^0, y, A, s) + \varepsilon_0 \qquad (3)$$

$$\text{public standpost}: \quad U_1 = w_1(q^1, y, M_S, A, s) + \varepsilon_1 \qquad (4)$$

$$\text{domestic piped water connection}: \quad U_2 = w_2(q^2, y, M_D, A, s) + \varepsilon_2. \qquad (5)$$

In these equations, M_S is the monthly charge for a public standpost and M_D is the monthly charge for a domestic

[16] This annex draws heavily on Ahmad *et al.* (2005).

connection. Income of the household is denoted by y. Arsenic awareness and concern is denoted by A. The vector s stands for all other socio-economic variables. The household will choose a domestic connection if U_2 is greater than U_0 and U_1. The conditions under which the household will choose a standpost, or reject both standposts and domestic connections, can be similarly defined. It should be noted that, when U_2 is compared with U_0, one is comparing the utility from a domestic connection adjusted for the monthly payment made with the utility from the conventional water source. Accordingly, the structure of equations specified is such that monthly charges for a standpost enters the equation for standpost and the monthly charges for a domestic connection enters the equation for domestic connection.

Though two charges were quoted to the respondents in the survey, one for capital cost and the other for O&M costs, these were combined into an equivalent monthly charge for the econometric analysis. The one-time payment for capital cost was converted into an equivalent monthly payment applying the interest rate, which was taken as 12% per annum[17]. This figure was added to the quoted monthly payment for O&M to estimate the total monthly payment to be made by households for piped water supply (separate figures for standposts and domestic connections).

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

$$w_1(q^1, y, M_S, A, s) = 0. \quad (6)$$

Similarly, one can find the average WTP for a domestic piped water connection as the value of M_D which satisfies the following equation:

$$w_2(q^2, y, M_D, A, s) = 0. \quad (7)$$

In other words, the average WTP is obtained as a non-linear function of the estimated parameters and the average values of explanatory variables. Using the function and the variance-covariance matrix of parameter estimates, the asymptotic variance and confidence interval for the estimated average WTP is computed.

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 values of income and other socio-economic variables were computed, and equations (6) and (7) applied. This process yields the total amount that households were willing to pay per month. In the next step, this was split into (a) willingness to pay for O&M costs, and (b) 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).

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[17] In 2001–2 when the survey was conducted, the rate of interest on deposits for two years or more with major banks in Bangladesh was 8–9% per annum. The interest rate for agricultural lending in such banks was between 12–16% per annum. The mid-point of the range of interest rates, i.e. 12% 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.