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Understanding social acceptability of arsenic-safe technologies in rural Bangladesh: a user-oriented analysis

Debasish Kumar Kundu[a,*], Aarti Gupta[a], Arthur P. J. Mol[a] and Mahbuba Nasreen[b]

[a]*Environmental Policy Group, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands*
**Corresponding author. E-mail: debasishk.kundu@wur.nl; kundudev@yahoo.com*
[b]*Institute of Disaster Management and Vulnerability Studies (IDMVS), University of Dhaka, Dhaka 1000, Bangladesh*

Abstract

Contamination of shallow tube well drinking water by naturally occurring arsenic is a severe societal and human health challenge in Bangladesh. Multiple technological interventions seeking to ameliorate the problem face hurdles in securing social acceptance, i.e. the willingness of users to receive and use a technology. While most papers focus on expert understanding of social acceptability, this paper analyzes how users themselves understand the factors shaping the social acceptability of safe drinking water options in rural Bangladesh. We then deploy such understanding to comparatively assess which factors users see as most important in securing social acceptance for three safe drinking water options in rural Bangladesh: the arsenic removal household (Sono) filter; the deep tube well; and an improved dug well. We draw on focus groups and semi-structured interviews with technology users in six villages across three districts to analyze how users assess the social acceptability of specific arsenic-safe technologies. Our findings highlight that factors such as availability, affordability and compatibility with existing water use practices, as understood by users, are key to securing users' acceptance of a specific arsenic-safe option. In concluding, we point to a future research agenda to analyze user-oriented social acceptability of arsenic-safe technologies in developing country contexts.

Keywords: Arsenic contamination; arsenic mitigation technologies; Bangladesh; Safe drinking water; Social acceptability

1. Introduction

Arsenic contamination of shallow tube well drinking water in Bangladesh is an urgent developmental and health challenge (Sekar & Randhir, 2009). Arsenic in groundwater is naturally occurring in Bangladesh, yet it severely limits access to safe drinking water for the rural poor, who are most reliant on shallow hand pump tube wells as their main source of drinking water (Atkins *et al.*, 2007; Chakraborti

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et al., 2010; Van Halem et al., 2010; Rammelt et al., 2014). The problem has its origins in a well-intentioned bid in the early 1970s by the Government of Bangladesh and the United Nations Children's Fund (UNICEF) to address the problem of contaminated surface water and provide the rural population with an alternative source of safe drinking water. An estimated ten million shallow tube wells were installed in rural households in Bangladesh to ensure a continuous supply of safe drinking water (van Geen et al., 2003). Initially, this ensured access to safe drinking water for 97% of the population, an impressive achievement (Smith et al., 2000). However, this rate dropped to 72% by the early 1990s, following the detection of naturally occurring arsenic in groundwater (Mahmud et al., 2007; Johnston et al., 2010; UNICEF, 2010).

Exposure to arsenic contaminated water can result not only in arsenicosis, which refers to a wide range of diseases from skin lesions to cancer, but also to an array of social problems (Nasreen, 2002). Depending on what arsenic threshold levels[1] are considered, an estimated 30–56.7 million people are currently exposed to arsenic-contaminated drinking water in Bangladesh (DPHE & JICA, 2009; Milton et al., 2012). In response to what has been termed the 'biggest mass poisoning' in history (WHO, 2000), the Government of Bangladesh developed the *National Policy for Arsenic Mitigation* in 2004, followed by an implementation plan to address the crisis (GoB, 2004a, 2004b). Over the last decade, various arsenic mitigation technologies and safe alternative drinking water options have been tested and disseminated in Bangladesh. These options can be grouped into two categories: (i) filter and treatment technologies that remove arsenic from contaminated shallow tube well water, such as household and community-level filter systems; and (ii) alternative safe water options, such as piped water supply, deep tube wells, improved dug wells, safe shallow hand pump tube wells and rain water harvesting (Hoque et al., 2004; Ahmad et al., 2006; Inauen et al., 2013). Although a wide array of such options have been tested and deployed, exposure of the rural population to arsenic remains high. Although these technologies and interventions can be efficacious in removing arsenic from drinking water or providing safe drinking water alternatives, research has consistently shown that many face hurdles in securing social acceptability (Mahmud et al., 2007; Shafiquzzaman et al., 2009; Johnston et al., 2010; Mosler et al., 2010).

In this paper, we thus analyze how users of three arsenic-safe technologies understand social acceptability. The three technologies we focus on include: a household arsenic removal filter system (the Sono filter) and two community-level alternative water provisioning technologies (a deep tube well and an improved dug well). In analyzing social acceptability of these three arsenic-safe technologies, our first key aim is to go beyond expert notions of social acceptability to delineate how users themselves understand and prioritize factors that shape social acceptability. Second, we draw on such user understandings to investigate the relative acceptability of each technological option for users.

We proceed as follows: the next section presents our research approach and methodology. We then distill from the literature a set of factors that may contribute to social acceptability of risk reducing technologies, in order to then investigate how such factors are understood by arsenic-safe technology users in Bangladesh. We next analyze the importance that users attach to each of the identified factors in securing acceptance (or not) of a given technology. We conclude by synthesizing and explaining the

[1] Thirty million people are exposed to arsenic contamination by consuming more arsenic in drinking water than the Bangladeshi safety limit of 0.05 mg/L, whereas 56.7 million people are at risk, according to the World Health Organization guideline value of 0.01 mg/L.

relative social acceptability for users of the three technologies in our study area, as revealed by our analysis.

2. Methodology and approach

This section explains our rationale for selecting the three technologies, the study areas, data collection techniques and analytical methods. As noted above, we selected three arsenic-safe technologies from the two categories noted above: deep tube well (70% of total installed arsenic mitigation options in Bangladesh) and improved dug well (given that surface water is prioritized within national arsenic mitigation policy), as two safe water alternatives, and the Sono filter, as an example of a household arsenic removal filter technology. A deep tube well (with a so-called force-mode Tara-Dev pump or suction-mode UNICEF Number 6 pump) is a community-level drilled well, generally more than 150 meters deep. The improved dug well is a community-level technology that combines a protected dug hole with a water-lifting device like a UNICEF Number 6 hand pump (see Appendix 1 for photographs of all three technologies, available with the online version of this paper). One improved dug well and one deep tube well usually serve approximately 10 households in the study areas. The Sono filter is designed to serve a single household by treating arsenic-contaminated water obtained from a shallow hand pump tube well. It consists of two small plastic buckets, flow controller, filter media (charcoal, river sand, brick chips inside) and an iron stand as base. The cost of a Sono filter ranges from US$35 to US$65, whereas one-time installation costs for a deep tube well (US $1,000) and improved dug well (US$900) are higher (Johnston *et al.*, 2010; Ravenscroft *et al.*, 2014). In the study areas, the provision of all three technologies was highly subsidized by the implementing agencies (the Department of Public Health Engineering or non-governmental organizations (NGOs)), who financed 90–95% of the total installation costs. In addition to the remaining installation costs, users were responsible for covering 100% of the operation and maintenance costs.

As the possibility of studying all three technologies in a single area was limited, we deliberately picked six villages from three districts (two villages per district) where arsenic contamination levels are moderately high to very high, and hence where these technologies are being deployed. In Uttar Suchipara and Daikamta, two villages in Chandpur district, where 96–97% of existing shallow tube wells were contaminated, the Department of Public Health Engineering (DPHE) has installed community-level deep tube wells since 2009. Manob Sakti Unnayan Kendro (MSUK), a local NGO, has deployed Sono arsenic filters since 2009 in Nawda Khemirdiar and Islampur villages of Kushtia district, where 60–84% of the tube wells were contaminated. The local NGO, Socio Economic Development Agency (SEDA), has deployed improved dug wells since 2008 in Shimulia and Pukhuria villages in Manikganj District, where 64–81% of the tube wells were contaminated (see Table 1).

In order to generate data on how rural users understand the factors shaping (their) acceptability of various arsenic-safe technologies, we organized nine focus group sessions (two with female and one with male users, per technology). In total, 90 users participated in focus groups (each of the nine sessions consisted of 10 users, thus a total of 30 users per technology). Two focus group sessions were held in the villages of Islampur, Uttar Suchipara and Shimulia (one each with male and female users per technology), while one focus group session with female users was held in each of the villages of Nawda Khemirdiar, Doikamta and Pukhuria (see Table 1). We focused more on female users because of their leading role in domestic water management. Generally, a housewife or household head (usually male) was invited from one household to participate in a focus group session. A total of 19 households

Table 1. Field research data.

Technology	District	Villages	No. of focus groups	Total participants Female	Male	Implementing agency
Deep tube well	Chandpur	Uttar Suchipara	2	10	10	Department of Public Health & Engineering
		Daikamta	1	10		
Sono filter	Kushtia	Nawda Khemirdiar	1	10		Manob Sakti Unnayan Kendro (NGO)
		Islampur	2	10	10	
Improved dug well	Manikganj	Shimulia	2	10	10	Socio Economic Development Agency (NGO)
		Pukhuria	1	10		

refused to participate in the sessions and were replaced by others. We were not able to detect any systematic bias (age, religion, income) in those refusing participation. In addition to focus groups, 21 in-depth interviews were conducted with users to gain further insight into aspects shaping their acceptability of the technologies. It should be noted that users participating in focus group sessions and in-depth interviews discussed only the specific technology they had been using.

Using data from focus groups, we compiled user understandings of a variety of factors assumed to shape social acceptability. Furthermore, we combined user interpretations of any given factor, regardless of which technology they were speaking about; we only distinguished between technologies if the three different technology user groups framed a given factor differently. As we elaborate in the next section, the factors we focused on were availability, ease of use, and affordability of the technologies, as well as user views on arsenic risk and water quality, and their current water use practices.

Subsequently, after focus group discussions, all users were asked individually to identify those factors they considered most important in shaping (their) acceptability of the technologies. Finally, they were asked to assess the overall acceptability of the technology they were currently using, and the reasons for their assessment. The average duration of each focus group (with 10 participants each) was two and half hours, and in-depth interviews lasted an hour. Furthermore, we collected data from secondary sources, including scientific journals, policy reports and media.

3. Social acceptability: a user's framework

3.1. Conceptualizing social acceptability: definitions and factors

A growing body of research in the fields of sociology, psychology and risk analysis has focused in recent years on identifying factors that shape social acceptability of risk-reducing technologies. This includes studies relating to arsenic contamination of water as well (Chakraborti *et al.*, 2010). Generally, how experts conceptualize the factors shaping social acceptability has tended to dominate existing social science analyses. A few studies have assessed the most preferable arsenic-safe option based on users' perspectives (see Hoque *et al.*, 2004; Kabir & Howard, 2007; Mosler *et al.*, 2010; Inauen *et al.*, 2013; Hossain & Inauen, 2014), yet these studies have not explicitly considered users' own understanding of the various factors that are often assumed to shape social acceptability, as we do here.

In making this our focus, we also offer a working definition of the notion of social acceptability, building on and extending previous scholarship. First, in line with recent writings, we view social acceptability not as a static one-time decision but rather as a dynamic process (Shindler & Brunson, 2004; Escoffier & Grandclement, 2010). Furthermore, we define it here as 'the willingness to receive and use' a given technology. We draw on existing literature (Davis, 1985; Hoque *et al.*, 2004; Howard *et al.*, 2006; Kabir & Howard, 2007; Madajewics *et al.*, 2007; Shafiquzzaman *et al*., 2009) to identify a set of factors contributing to social acceptability. We then categorize such factors into two groups: first, attributes of the technological intervention itself; and second, user perceptions and water-related practices (see Figure 1).

Within the first category, we identify three factors: *availability* in sufficient quantities of the technology in question; its *ease of use*; and its *affordability* in terms of installation, operation, maintenance, and replacement costs. Within the second category, we include *risk awareness* about arsenic contamination, arsenicosis and risk versus benefits of using specific technologies; *water quality beliefs* (concerning, for example, taste, smell, temperature, arsenic-free status, etc. of different water sources); and *water use practices* (such as relying on one source for multiple uses, as well as unlimited versus rationed use etc.).

3.2. User understandings of diverse factors shaping social acceptability

As mentioned earlier, we relied on focus groups to investigate users' own understandings of various factors shaping social acceptability (Kuypers, 2009). It is important to note that in delineating such

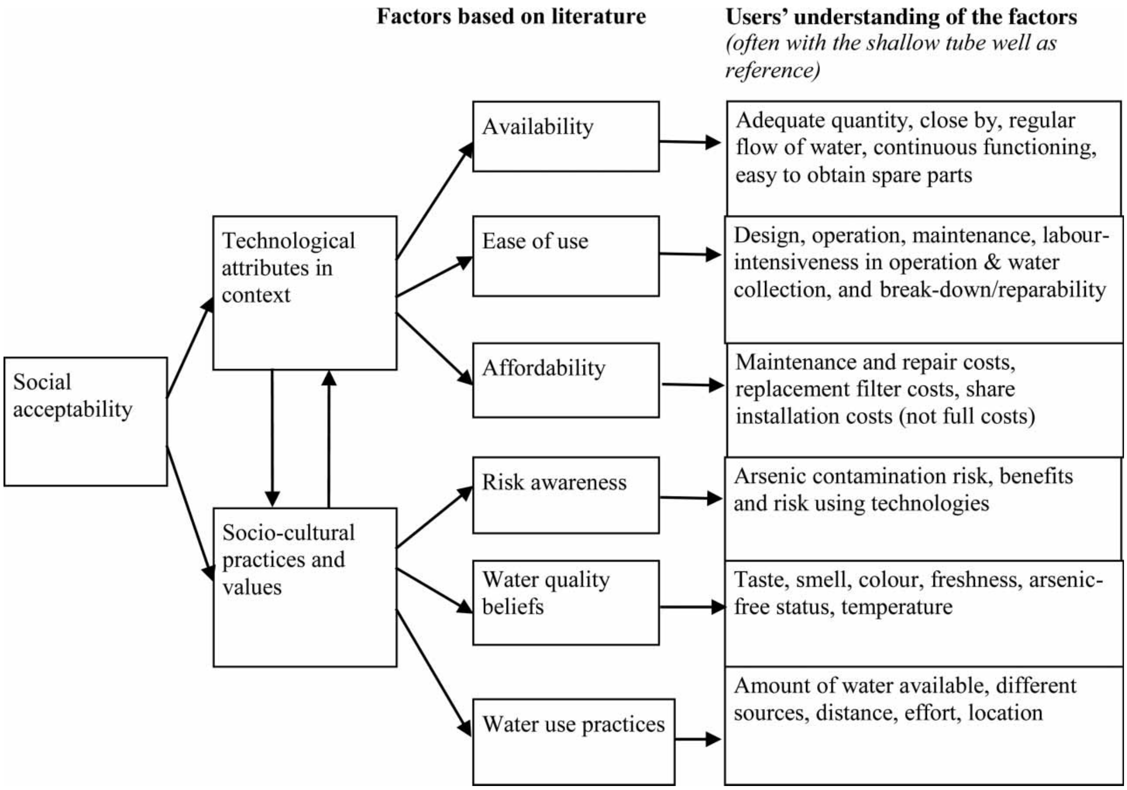

Fig. 1. Factors shaping social acceptability.

factors here, we do not see them as mutually exclusive or empirically distinct, but rather as (overlapping) analytical categories.

With regard to availability, all users received a technology only when the implementing agencies made it available to them. Hence, in terms of shaping social acceptability, the factor 'availability' could potentially be rendered redundant as a result of this. Nonetheless, our findings suggested that understanding of availability varied somewhat across the three technology user groups. While all three user groups understood availability to mean an *adequate number* of technological units being available to meet safe water demand on a regular basis, Sono filter users also emphasized the regular and uninterrupted availability of the filter, which includes availability of spare parts in local markets. Users of deep tube wells and improved dug wells, on the other hand, understood 'availability' to also include an adequate number of units being available at *convenient locations*.

Ease of use as a factor shaping acceptability was understood in a similar manner by the three user groups to mean aspects relating to design, operation, labour-intensiveness, and maintenance. Such understandings of ease of use were shared across all technological user groups partially because the shallow hand pump tube well served as a shared comparative point of departure for all groups in their understandings of ease of use. User understandings of affordability were also shaped by shared experiences across the three technology user groups. First, few users had a specific idea about the actual costs (market price) of the technologies they were using, as all were highly subsidized. Second, users considered it the responsibility of government (and NGOs) to provide them with technologies, regardless of costs. Nonetheless, when asked to imagine a situation without highly subsidized technologies, deep tube well and improved dug well users emphasized high upfront installation costs as an important element in their view on affordability, whereas Sono filter users also stressed the importance of costs related to filter and filter media replacement, in addition to first-time acquisition costs.

In articulating their understandings of how risk (relating to consuming arsenic contaminated water) influenced social acceptance of a given option, all users emphasized three key aspects: (i) the negative health consequences of consuming arsenic contaminated water; (ii) the (related) risks of not using arsenic-safe technologies; and (iii) possible risks (but also benefits) of using specific arsenic-safe technologies. These then shaped their assessment of the risks associated with drinking (or not) water from the alternative safe drinking water option that they had access to. Another key set of factors shaping acceptability related to user water quality beliefs, with users of different technologies emphasizing the importance of aspects such as (differing) taste, smell, colour, freshness, arsenic-free status and temperature of the water, in comparison with shallow hand pump tube well water as their frame of reference. Similarly, all users considered how their water use practices (had to) change with alternative, arsenic-safe technologies, again with the shallow hand pump tube well as their reference point. Broadly, in considering this, users emphasized the importance of the overall amount of water available through a given option, as well as the challenge posed by the need to shift between multiple technologies in accessing water for different purposes (such as drinking versus washing or cooking). They also noted their views on how geographical aspects of (changed) water use practices (distance, effort, location of alternatives) shaped their acceptability of a specific option.

Diverse factors shaping social acceptability, according to the above delineated user understandings, are shown in Figure 1.

4. A user's perspective of social acceptability: comparing different factors

Based on these user understandings of the factors determining social acceptability, this section analyzes which factors were seen by users themselves to be most important in shaping their own willingness to receive and use three arsenic-safe drinking water options: the Sono Filter, deep tube well, and improved dug well.

Figure 2 depicts an overview of our findings, showing the percentage of each technology user group who viewed a given factor as important to shaping their acceptability of that specific arsenic-safe option. We discuss these findings in detail below.

4.1. Technological attributes in context: availability, ease of use and affordability

In this section, we outline our findings relating to how users viewed the technological attributes of the three examined technologies – Sono filter, deep tube well and improved dug well – in determining social acceptability, i.e. their willingness to receive and use each option. We discuss below users' views on three factors: availability, ease of use, and affordability.

Availability of arsenic-safe technologies. In securing social acceptability of given technologies from a user perspective, the factor 'availability', as understood by users, proved important for all Sono filter users, but only for half of the deep tube well (50%) and improved dug well users (56.67%) (Figure 2). This was especially because new Sono filters and spare parts were not available in the local markets, and could only be provided by the implementing agency during the project period. In addition, 40% of the Sono filter users experienced a breakdown of their filter within one year after use. In practice, very few filters served a life span of five years, due to poor maintenance. One Sono filter user interviewee (10 December 2011) noted that, 'a few years ago, an NGO provided us a filter that we used until it was

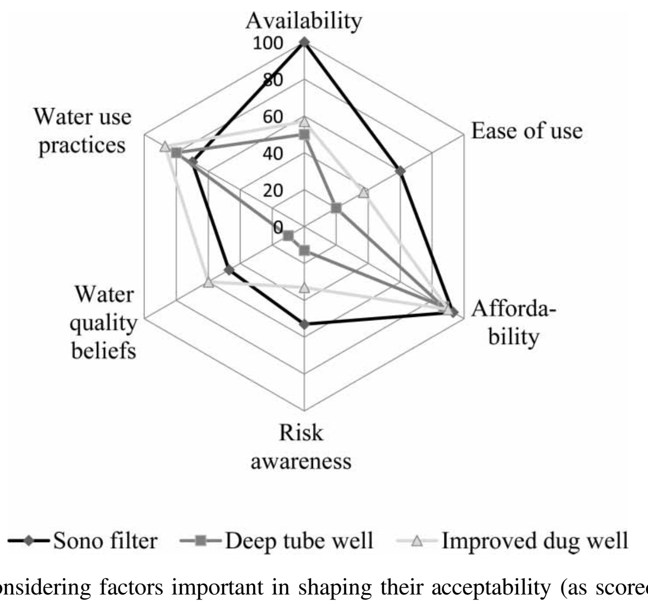

Fig. 2. Percentage of users considering factors important in shaping their acceptability (as scored by the users; $n = 90$).

broken after one year. Spare parts are not available in the local market and we have no other option but depending on the NGO for getting such a filter.' Consequently, the same household continued to use contaminated shallow tube well groundwater, as no new filter became available from the implementing agency. Therefore, dependency on the NGO for receiving the filter and non-availability of spare parts significantly lowered social acceptability of this technology, in the eyes of its users.

In the same way, availability of both the deep tube well and the improved dug well was entirely dependent on the projects. Female users revealed that both these technologies had high longevity, if maintained properly. But availability of an adequate number of units to serve demand in the villages was of major concern. As one deep tube well user noted (interview 4 January 2012), 'we need more deep tube wells, as our village, where 3,000 people live, has only four deep tube wells, which is inadequate'. Nonetheless, the availability of spare parts in local markets and assurance of getting new deep tube wells through government projects contributed to securing greater acceptability of this technology. In contrast, in the case of the dug well, the lack of spare parts in the local markets (except for the hand pump) and no assurance of getting new improved dug wells from the NGO in coming years constrained the acceptability of the improved dug well. Furthermore, the selection of locations for installing community-level technologies (both deep tube well and improved dug well) proved crucial for ensuring social acceptability of these technologies among users. Half the users of both the deep tube well and improved dug well were concerned with the aspect of location, as socio-religious norms do not allow adult and young women to source water from a distant community spot. Therefore, availability of an adequate number of deep tube wells and improved dug wells at *short-distance locations* was seen as vital to securing social acceptability of these technologies.

Hence, the lack of availability of the Sono filter (and filter media) after the project period ended lowered its social acceptability, whereas the (potentially) inadequate number of deep tube wells and improved dug wells at suitable locations close by lowered, to some extent, social acceptability of these technologies. The long lifespan and government's assurance of supplying more deep tube wells in coming years enhanced social acceptability of this specific option.

Ease of use. In the case of the household-level Sono filter, technological design, operation and maintenance (and related labour intensiveness) and vulnerability to breakdown were central concerns to the users in assessing ease of use. Around 60% of the Sono filter users considered ease of use to be important to securing acceptability (Figure 2). Among these users, two-thirds faced periodic break-down of the Sono filter. Subsequently, the iron filter stand had been converted often into a cloth-drying rack, whereas the plastic buckets had been turned into storage pots for preserving rice and vegetables. As noted in an interview with a female Sono filter user (12 December 2011), the poor plastic quality made the bucket of the Sono filter system fragile and prone to damage, hindering its long-term usability. In general, many female users noted that the maintenance and cleaning of filter media and of the two buckets was troublesome and labour intensive. Furthermore, users were concerned with slow filtration rates and clogging, which made them reluctant to use the filters regularly.

On the contrary, 80 percent of the deep tube well users did not experience major problems in using the technology, which contributed to enhanced social acceptability. This could be because the users already had adopted operation and maintenance routines for the tube well technology. Male users of deep tube wells were better able to repair small, regularly occurring, technical problems, which was not the case with the household filter and the improved dug well. However, 20 percent of deep tube well users noted that pressing the handle was laborious for female users, in particular during the summer, requiring due consideration in securing long-term use and acceptability. The collection of water from community wells was also found laborious for female users living at greater distances. About one-third of the improved dug well users found ease of use crucial in ensuring social acceptability (Figure 2). A few of these users highlighted the problem of potential microbial contamination of the wells, making regular cleaning (for example, chlorination through using bleaching powder) essential. During the dry season (March-August), groundwater levels are usually lower and users cannot get a sufficient amount of water, particularly from improved dug wells. Furthermore, in the monsoon season, improved dug wells in low-lying areas, like Manikganj, are vulnerable to flooding. Hence, seasonal malfunctioning of improved dug wells and their troublesome cleaning hindered their social acceptability. In sum, compared to the Sono filter and improved dug well, the deep tube well was less affected by problems associated with ease of use in securing social acceptability.

Affordability. After the detection of arsenic in groundwater, the users who had recently installed a shallow hand pump tube well for US$100–130 were now required to spend money once again on arsenic-safe technologies. In general, all three arsenic-safe technologies are costly for users, and hence installation of these three technologies was perceived to be impossible without the support of implementing agencies. As a result, all three arsenic-safe options were strongly supply-driven and project-dependent.

This notwithstanding, our findings showed that users considered affordability a crucial factor in ensuring social acceptability of the technologies (93% of Sono filter, 87% of deep tube well, and 90% of improved dug well users; Figure 2). In theory, for Sono filters, users had to pay a small share (US$4.5) of the filter cost, yet in practice they only paid for transportation costs. On the other hand, a group of 10 households was required to spend US$58–65 collectively as a community contribution to receiving a deep tube well or an improved dug well. The community-level technologies (deep tube well and improved dug well) were mostly installed in the courtyards of influential and solvent families, as these families covered the total community contribution on behalf of the user groups, and sponsored the location for installing the technology. Hence, the majority of users did not financially contribute to installing the arsenic-safe technology. Although the installation cost was relatively high for community-level technologies, the actual cost of the Sono filter was much higher, considering its short life time (five years in theory, much less in practice according to focus group participants), service coverage and required replacement cost of filter media once every two years. In contrast, despite having a high installation cost, the long life time (more than 20 years) of the deep tube well (and improved dug well, if not malfunctioning) made these technologies cost effective, compared to the Sono filter.

In three cases, users did not want to spend US$25 to repair a community-level improved dug well, as mentioned by host households (who were caretakers of the technology). Similarly, all Sono filter users did not want to spend money for replacement of filter media, let alone for buying a new filter. Hence, affordability is clearly a driving concern in determining social acceptability of the Sono filter. According to the participants of focus group sessions and the individual interviewees, no new households showed willingness to pay for an improved dug well in the post-project period, when households had to cover the full installation costs. Many villagers showed interest in installing a deep tube well at community-level, if the installation costs were somewhat reduced or subsidized. The implementing agencies (DPHE and NGOs) that cannot cover (part of) the installation costs face difficulties in securing social acceptability of these technologies, as they are not affordable in poor rural areas.

4.2. User beliefs and practices: risk awareness, water quality beliefs and water use practices

In this section, we outline our findings on how user understandings of arsenic risks, their beliefs about water quality, as well as their water use practices at individual and community level shaped their acceptability of the three examined technologies – Sono filter, deep tube well and improved dug well.

Risk awareness. Our research revealed that varying levels of user awareness of risks associated with drinking arsenic contaminated water, and the health benefits of using arsenic-safe technologies, did influence acceptability of the specific technological options (various interviews). As Figure 2 shows, about half of the Sono filter users (53%) linked their awareness of risk to greater acceptability on their part of the technology in question, while such a link was significantly lower for deep tube well (13%) and improved dug well users (33%). The high risk awareness amongst Sono filter users is explainable by the fact that female Sono filter users (20, but no male users) received training on how to use the technology, compared to no female users, and only five and six male users, of deep tube well and improved dug well respectively (i.e. those who were caretakers of the technology). Another reason for the elevated risk awareness among Sono filter users was the presence of a large number of arsenicosis patients (594) in adjacent villages. Despite this difference in risk awareness across technology user groups, all users did have basic knowledge about the negative consequences of consuming arsenic contaminated water, but not all had detailed and specific knowledge. For instance, more than half of all arsenic-safe technology users believed that arsenicosis is a contagious disease (focus group sessions) suggesting that risk-related information was not always interpreted as intended.

Female Sono filter users were better informed about the potential (health) benefits of using arsenic-safe technologies, as compared to female users of the deep tube well and improved dug well. However, male Sono filter users were found to be reluctant to acknowledge the benefits of these arsenic-safe technologies. As one participant in a focus group session (14 December 2011) noted, ‘my mother [has been] an arsenicosis patient for three years but I am not, although both of us drank water from the same contaminated source. Then why should I use the filter?’ A challenge in linking risk awareness to greater social acceptability for all three technologies is that the clinical manifestation of arsenicosis takes up to 10–15 years. Such long latency periods do not aid in increasing awareness of risk and a concurrent desire to avoid risk by using arsenic-safe technologies. As a result, 40% of Sono filter users, whose filters were abandoned, started relying on contaminated tube wells again, instead of replacing the old filter, despite their overall higher levels of risk awareness. Similarly, one-third of the improved dug well users continued to rely on contaminated shallow hand pump tube well water, when the dug well technology was periodically dysfunctional. Deep tube well users had fewer instances of such dilemmas, since the technology was functional for a longer term, and year round.

With regard to risk perceptions relating to use of the alternative technology itself, deep tube well users considered this particular technology to be very safe. Sono filter users, and improved dug well users, were only to a minor extent concerned about possible risks related to use of these specific technologies. For instance, although Sono filter users were instructed to put the filter sludge in a pot to avoid adverse health effects from exposure, no one was found to be concerned about this aspect. In addition, no Sono filter user knew how long the filter media would continue to remove arsenic from contaminated water. Similarly, users of improved dug wells did not express concern about potential microbial contamination. Furthermore, neither user group considered testing the water in order to detect the presence of arsenic and other (microbial) contaminants therein. These findings suggest, paradoxically, that instead of higher risk awareness resulting in higher social acceptance of arsenic-safe options, in certain instances, lower awareness and/or concern with the risks associated with these technologies led to higher social acceptance, since users ignored such risks. This is an important dynamic to keep in mind in assessing the linkages between levels of awareness about potential risks and benefits associated with use of specific technologies, and their social acceptance.

Water quality beliefs. Although arsenic contamination does not induce any change in colour, smell and taste of water, users often considered arsenic – and even arsenic-safe technologies – as being responsible for causing such changes. Improved dug well users exhibited the strongest link between (their perceptions of) water quality, and their acceptance of the relevant arsenic-safe technology. These users noted problems with the taste, colour and smell of dug well water, and their perception that it was not fresh, because it was stored in the protected dug. Sono filter users also perceived a lack of freshness in filtered water. In contrast, the deep tube well was perceived by users as providing fresh and tasty water. A dominant additional belief among Sono filter users was that using filtered water could cause cold in the chest during winter. This discouraged users, especially elderly people and children, from drinking filtered water, and/or reduced the amount of water intake, despite efforts of implementing agencies to convince users that this was not the case.

In addition, water quality beliefs centered around arsenic itself were also linked to varying social acceptability of arsenic-safe technologies, as focus group sessions showed. Thus, some Sono filter and improved dug well users believed that these two technologies did not adequately remove arsenic from the ground water and/or could not deliver arsenic-safe water, because no chemicals were used. Widespread information provided by governmental agencies and NGOs in earlier decades was that water from dug wells was not pure and required decontamination; which hindered its acceptability, despite the fact that the technology had since been upgraded. Furthermore, some users of all three technologies considered arsenic contamination to be a curse of God, and hence were not prepared to take action themselves in avoiding the contamination; although they did accept using given arsenic-safe technologies. Deep tube well users, on the other hand, did not articulate such water quality related beliefs that discouraged them from accepting and using the technology.

In sum, user beliefs about water quality had considerable influence on the social acceptability of various arsenic-safe technologies. As Figure 2 shows, more than half of the improved dug well users (60%) as well as almost half of the Sono filter users (47%) considered these beliefs to be of major importance for the social acceptability of these two technologies, which was much less the case among deep tube well users (10%).

Water use practices. Local water use practices in the study areas were all shaped by longstanding use of the shallow hand pump tube well prior to the arsenic contamination crisis, which enabled users to get an unlimited quantity of water from their own backyards, and in quantities sufficient to serve multiple purposes (drinking, cooking, cleaning, bathing). These water use practices had to change with the introduction of arsenic-safe technologies, since the unlimited access to drinking water provided by the shallow hand pump tube well to each rural household was no longer available. In one focus group session with Sono filter users (12 December 2011), one participant noted that,

> '*Since we are informed about contamination, we lost our traditional control and access over unlimited amounts of drinking water. In addition, we need to rely on other sources of water, such as ponds*

and canals, along with contaminated shallow hand pump tube wells, for cooking, bathing and household activities.'

Most Sono filter users thus did not use filtered water for cooking, although one third of them occasionally used filtered water for cooking rice, as they believed the water enhanced the taste. In addition, two-thirds of Sono filter users argued that these filters were unable to fulfill households' demand for drinking water, as it took too long for the water to move through the filter. Thus, use of the Sono filter required two changes to the traditional water use practices: first, relying on different water sources and technologies for different purposes; and second, limitations on the quantity of available safe drinking water.

Deep tube well and improved dug well users highlighted the importance of such changes as well, and also noted added significance of changed water collection practices. Collecting drinking water from a distant source, such as a community-level deep tube well and improved dug well, is often considered time-consuming and labour-intensive, putting additional burden on females. We found that female users from distant households had to continue to rely on contaminated shallow hand pump tube wells for purposes other than drinking and cooking. Overall, a high percentage of users across all three technological options (70% of Sono filter, 80% of deep tube well and 87% of improved dug well users) stated that the required changes in water use practices are significant in shaping social acceptability (Figure 2).

4.3. Comparative acceptability by users of the three arsenic-safe options

Following on from focus group discussions about the relative importance accorded by users to the different factors shaping social acceptability, we concluded our empirical data generation by asking all 90 participants in the focus groups to (individually) qualitatively assess their overall level of acceptability of the technology in question, across three scales (highly acceptable, moderately acceptable, and minimally acceptable) (Table 2).

As Table 2 reveals, despite the problems associated with availability at an appropriate location, affordability (cost sharing), and changes in water use practices (including additional time and labour spent to collect water), the technological option of the deep tube well is seen as a highly acceptable technology by three-quarters (77%) of its users. This finding was also reinforced by the data generated in the focus group sessions and individual interviewees. In contrast, half of the Sono filter users graded this arsenic-safe option as moderately acceptable, whereas one-third considered it to be only marginally acceptable. Similarly, 47% of the improved dug well users considered this technology to be marginally acceptable, whereas 43% viewed it as moderately acceptable. Very few Sono filter users (13%) and improved dug well users (10%) assessed their technology to be highly acceptable. Concerns with

Table 2. Overall acceptability by users of three arsenic-safe technologies ($n = 90$).

Technologies	Highly acceptable *N* (%)	Moderately acceptable *N* (%)	Marginally acceptable *N* (%)	Total *N*
Sono filter	4 (13)	15 (50)	11 (37)	30
Deep tube well	23 (77)	4 (13)	3 (10)	30
Improved dug well	3 (10)	13 (43)	14 (47)	30

availability, affordability, perceived water quality and changed water use practices were the main reasons for this (as documented earlier in Figure 2). Focus group discussions and interviews revealed, in addition, that very few rural people who were exposed to the risk of arsenic contamination wanted to receive and use the improved dug well technology. Focus groups with Sono filter users also indicated that households did want to receive Sono filter technology, but only if filters were highly subsidized, as it would take away a major (financial) worry, and would enable female users to manage safe drinking water within their households, and thus conform to social norms.

5. Discussion and conclusion

Since the social acceptability of arsenic-safe technologies is key to their successful dissemination in rural Bangladesh, this paper assessed users' own perspectives on social acceptability of three technologies: the Sono filter, deep tube well and improved dug well. In doing so, we had a two-fold aim. First, we assessed how users themselves understood a diverse array of factors influencing their acceptance (or not) of these technologies. Second, we drew on these user understandings of key factors shaping social acceptability to estimate the relative acceptability of each technology to its users in our areas of study. Most studies in this field (e.g., Hoque *et al.*, 2004; Howard *et al.*, 2006; Mosler *et al.*, 2010; Inauen *et al.*, 2013) draw on expert conceptualizations of social acceptability in assessing whether arsenic-safe options are likely to secure social acceptance, even those that study users' views. Our investigation has focused, instead, on how technology users themselves understand the factors that constitute social acceptability.

With regard to such user understandings, our findings reveal that, although all three arsenic-safe technologies we examined were highly subsidized and made available through projects, user views varied with regard to availability and affordability of the technologies, as key factors shaping their social acceptance of them. Despite the subsidized provision of the technology, Sono filter users highlighted its short life span, recurrent costs (relating to installation, operation, maintenance, and filter replacement), and lack of an uninterrupted supply of filters as crucial factors inhibiting their acceptability of it in the long run. Deep tube well and improved dug well users, however, saw these technologies as being more affordable and available, notwithstanding higher initial installation costs and potentially inconvenient locations of such technologies.

Our analysis revealed, furthermore, that additional factors assumed to shape social acceptability of a given technology, such as ease of use, risk awareness, water quality beliefs, and water use practices, were all understood in a similar manner by users across all three technologies. This is explainable by the fact that user understandings of these factors were strongly influenced by their collective prior experiences with the shallow hand pump tube well as a reference technology.

With regard to the second aim of our analysis, to draw on user understandings to assess the relative importance of different factors in shaping social acceptance of the studied technologies, our analysis shows that not all factors were seen by users as equally important. In general, availability, affordability and water use practices were seen as the most crucial in securing acceptance of all three arsenic-safe technologies. This finding again diverges somewhat from earlier studies that have focused most attention on ease of use (operation and maintenance) and user perceptions of water quality beliefs (taste, smell and colour).

In particular, *availability* of alternatives has not been considered an influential factor shaping social acceptability in earlier studies. One reason is that since arsenic-safe options were being made available to users by project developers or the government, the starting assumption of earlier social acceptability studies has tended to be that an option is already available to users. Our study is important in documenting, however, that user understanding of availability vary (for instance, including not only one-time access but also an assurance of getting a technology in an uninterrupted and timely manner), and that such varied understandings play important roles in shaping acceptability of a specific arsenic-safe option.

With regard to *affordability*, our analysis reveals that the deep tube well is regarded by users as a cost-effective technology, compared to the other two arsenic-safe options, a finding that is consistent with other research (Hossain & Inauen, 2014). Other analyses (e.g., Mosler *et al.*, 2010; Inauen *et al.*, 2013; Hossain & Inauen, 2014) have also highlighted that perceived (lack of) affordability is a challenge in securing social acceptability of arsenic-safe technologies. Our analysis is aligned with such previous work, in highlighting that poor users cannot afford the (limited) cost sharing involved in their dissemination and use, despite heavy subsidization of the technologies in question. We also show, furthermore, how users' perspectives on affordability and availability are linked. For example, where wealthier families pay the full cost of cost-sharing arrangements between providers and users for the deep tube well and improved dug well, this has resulted in the technologies being placed at a location desirable and suitable for them, thus potentially lowering accessibility of these technologies for poor users. While some studies have noted the contribution of wealthier people in cost sharing, making such options more affordable for others (e.g., Inauen *et al.*, 2013), they have not always noted linkages with other factors shaping social acceptability, in this case between availability and affordability.

With regard to changing *water use practices*, this has been examined in other studies only in terms of distance to water source and water collection times (e.g., Hoque *et al.*, 2004; Shafiquzzaman *et al.*, 2009; Mosler *et al.*, 2010), rather than also assessing aspects such as limited versus unlimited quantities of water available, and issues relating to one versus multiple source of water to serve multiple needs.

The remaining factors assessed in our analysis, including ease of use, risk awareness, and water quality beliefs, have had, our findings show, a greater impact on (low) user acceptability of the Sono filter and improved dug well (as compared to the deep tube well), a finding that is in line with earlier studies (Alam & Rahman, 2011; Inauen *et al.*, 2013; Hossain & Inauen, 2014). This is because users do not differentiate between the deep tube well and shallow hand pump tube well (their reference technology) in terms of ease of use, risk awareness, and water quality.

Finally, in distilling a comparative overview of the level of social acceptance of each of these arsenic-safe technologies from the users' perspectives, our analysis shows that the deep tube well is graded as highly acceptable by most of its users, consistent with some previous studies (Paul, 2004; Mosler *et al.*, 2010; Inauen *et al.*, 2013; Hossain & Inauen, 2014). The improved dug well and Sono filter are seen as less acceptable by most users. This is in contrast to some other studies (e.g., Shafiquzzaman *et al.*, 2009; Inauen *et al.*, 2013), which have claimed that the Sono filter was a highly preferred option, along with the deep tube well, by most users. Our findings do replicate the conclusion of Inauen *et al.* (2013) and Hossain & Inauen (2014) that the improved dug well technology is the least preferred option. Compared to other arsenic-safe technologies, especially users' risk awareness (microbial contamination), and water quality beliefs (smell, taste and colour) hinder the acceptability of the improved dug well.

We conclude, then, that also from a technology user's perspective, the installation of an adequate number of deep tube wells at convenient locations is likely to be the most socially acceptable arsenic-safe option of those currently disseminated in rural Bangladesh. With regard to the Sono filter, despite problems associated with availability, ease of use, affordability and water use practices, our findings highlight that such filters *could* gain greater social acceptability in those regions where the deep tube well is not feasible (e.g. for geohydrological reasons), provided such aspects are addressed. The improved dug well is the least viable arsenic-safe technology, given its low social acceptability.

In concluding, our analysis suggests that instead of relying on expert conceptualizations of social acceptability alone, user understandings of what constitutes social acceptability provide an important avenue through which to grasp why certain technologies are judged to be more acceptable than others. As such, this paper has advanced a 'user's framework' on social acceptability, one that provides new insights into how users themselves view the importance of factors such as availability, affordability and compatibility with existing water use practices in shaping social acceptability. It has also documented how other factors, such as ease of use, risk awareness, and water quality beliefs, shape the varying social acceptability of specific arsenic-safe options. Our analysis also suggests, moreover, that as a dynamic rather than a static process, securing greater social acceptability of any specific option can become feasible, if implementing agencies and policy actors focus on user views on existing hurdles to acceptance.

The analysis in this paper can be usefully augmented by future research on the interrelatedness of the factors studied here in determining social acceptability, as well as the differences in understandings of social acceptability between users and non-users in the same geographical location. It could also be useful to compare divergent understandings of social acceptability between users and other key actors (such as local government or technology providers). Finally, comparison with arsenic-safe alternatives not analyzed here, including well switching, or piped water supply systems, as two promising alternatives, would be important.

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