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Enhancing arsenic mitigation in Bangladesh: Findings from institutional, psychological, and technical investigations

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HIGHLIGHTS

- Institutional, psychological, and technical aspects of arsenic mitigation were studied.
- Both institutional stakeholders and populations at risk supported deep tubewells.
- Self-efficacy and social norms drive behavior and are supportive of deep tubewells.
- Deep groundwater can provide drinking-water free from arsenic and other chemicals.
- Higher priority should be given to installing deep tubewells in high-risk areas.

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ABSTRACT

As part of a trans-disciplinary research project, a series of surveys and interventions were conducted in different arsenic-affected regions of rural Bangladesh. Surveys of institutional stakeholders identified deep tubewells and piped water systems as the most preferred options, and the same preferences were found in household surveys of populations at risk. Psychological surveys revealed that these two technologies were well-supported by potential users, with self-efficacy and social norms being the principal factors driving behavior change. The principal drawbacks of deep tubewells are that installation costs are too high for most families to own private wells, and that for various socio-cultural-religious reasons, people are not willing to walk long distances to access communal tubewells. In addition, water sector planners have reservations about greater exploitation of the deep aquifer, out of concern for current or future geogenic contamination. Groundwater models and field studies have shown that in the great majority of the affected areas, the risk of arsenic contamination of deep groundwater is small; salinity, iron, and manganese are more likely to pose problems. These constituents can in some cases be avoided by exploiting an intermediate depth aquifer of good chemical quality, which is hydraulically and geochemically separate from the arsenic-contaminated shallow aquifer. Deep tubewells represent a technically sound option throughout much of the arsenic-affected regions, and future mitigation programs should build on and accelerate construction of deep tubewells. Utilization of deep tubewells, however, could be improved by increasing the tubewell density (which requires stronger financial support) to reduce travel times, by considering water quality in a holistic way, and by accompanying tubewell installation with motivational interventions based on psychological factors. By combining findings from technical and social sciences, the efficiency and success of arsenic mitigation in general – and installation of deep tubewells in particular – can be significantly enhanced.

1. Introduction

The importance of geogenic contamination of drinking-water only became evident upon discovery of widespread arsenic contamination in Bangladesh in the 1990s. The National Hydrochemical Survey of 2000 (BGS/DPHE, 2001) found that naturally occurring arsenic was widespread in the shallow aquifer (less than 150 m in depth) but largely absent from

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deeper groundwater. Water samples (from shallow and deep tubewells) exceeded the WHO provisional Guideline Value of 10 μg/L and the Bangladesh Drinking Water Standard of 50 μg/L in 42% and 25% of samples, respectively. 8.9% of samples contained more than 200 μg/L, up to a maximum of 1660 μg/L. The authors estimated that out of a total population of 125 million people, 35 million people were exposed to water above 50 μg/L, and 57 million people were exposed above 10 μg/L.

These findings spurred a series of high-profile mitigation efforts. However, after an initial period of intense focus on arsenic, attention drifted away, both at the local and national scales. The main arsenic-specific project during this period was the Bangladesh Arsenic Mitigation and Water Supply (BAMWSP) project, supported by the World Bank. Running from approximately 1998 through 2007, BAMWSP spent approximately $22 million on testing, patient identification, and installation of alternative drinking water supply options. In 2004, the government issued a National Policy for Arsenic Mitigation (GOB, 2004a) and Implementation Plan for Arsenic Mitigation (GOB, 2004b). The National Policy stated that mitigation efforts should give preference to surface water over groundwater as a water supply source, and that piped water systems should be promoted wherever feasible. The Implementation Plan was more explicit with respect to groundwater; it stated that in coastal areas where the deep aquifer had been well characterized, deep tubewells could be used for arsenic mitigation, but in other areas (including most of the highly affected zones), surface water or very shallow groundwater should be tried first. Thus early mitigation efforts focused on technologies such as pond sand filters and hand-dug wells. While these water sources are largely free from arsenic, they are more vulnerable to fecal contamination. Lokuge et al. (2004) argued that switching from arsenic-contaminated groundwater to fecally-contaminated unimproved sources could actually increase the burden of disease; (Howard et al., 2006) surveyed different arsenic mitigation options and calculated the burden of disease expected from arsenic and microbial contamination, expressed in Disability-Adjusted Life Years (DALYs). In comparison to shallow tubewells, deep tubewells were predicted to cause a much lower burden of disease; rainwater collection had a lower burden from arsenic but higher burden from microbial contamination leading to an overall similar burden; and both dug wells and pond sand filters lead to approximately an order of magnitude more disease, wholly attributable to poor microbial quality. These findings lent support to the already widespread practice of giving preference to deep tubewells over other sources in mitigation programs. Piped water systems are a new phenomenon in rural Bangladesh, and there is so far little documented experience on either the financial sustainability of such systems, or the quality of water they are able to deliver. Experiences from other countries suggests that intermittently operated piped water schemes are vulnerable to fecal contamination, and do not necessarily deliver water which is safer than point sources (Klasen et al., 2012).

By 2009 180,000 alternative water sources had been installed in arsenic-affected areas. Using estimates of the population served by each technology, over 11 million people were estimated to have arsenic-free water in the affected areas (DPHE/JICA, 2009).

Capital costs of all of these alternatives are several times higher than for shallow tubewells, so while individual households can relatively easily afford private shallow tubewells, only wealthy families enjoy their own deep tubewells. Government programs (by far the largest contributor to deep tubewell installation) ask communities to contribute about 10% of the capital costs for installation of communal deep tubewells. However, these water points have not been preferentially sited in the worst-affected areas: 61% of the safe water supplies were installed in the 16% of unions where fewer than 20% of tubewells were contaminated (DPHE/JICA, 2009). If these water sources had been installed in more highly affected areas, exposure could have been reduced more efficiently.

In 2009, a second national survey (UNICEF/BBS, 2011) was conducted, which found much less arsenic (Table 1). These figures are encouraging, and suggest that exposure may have been reduced by roughly a quarter at the 10 μg/L level, and by greater factors at higher levels (Table 2). During the same period, the population increased by nearly a third. Taking the population-adjusted figures, it seems that the number of people exposed to the highest levels (>200 μg/L) has been reduced by more than one half, and the population drinking water not meeting national standards reduced by approximately one third. Considering the stricter 10 μg/L level, however, progress is only just keeping up with population growth. However, these gains may be overstated: the 1999 survey measured arsenic at the water source, and the 2009 measurements were made on water samples collected in households. While the lower contamination levels could reflect people systematically switching to less contaminated sources, it is also possible that arsenic levels can be slightly reduced during household storage, due to oxidation and precipitation of iron which can scavenge arsenic from solution.

While arsenic exposure has clearly been reduced, mitigation has proceeded much more slowly than originally hoped and planned, and the public health burden remains unacceptably high. Health impact models suggest that at least 24,000 deaths per year are caused by arsenic (Flanagan et al., 2012), which is larger than the number of child deaths caused by diarrheal disease (National Institute of Population Research and Training (NIPORT) et al., 2013). Reducing this disease burden should be a high priority for the government and development partners.

Mitigation of arsenic in drinking water is a complex task, involving a broad spectrum of stakeholders, from policy makers, regulators, facilitators, implementers, to social groups and end users of water. The selection of suitable mitigation measures and the ways they are implemented all have significant impact on the results of the mitigation. In practice, it is important to involve stakeholders from the whole range of the spectrum and at all stages in the process to ensure that the measures implemented are the most preferred. This leads to a need for integrated analysis of individual measures from the aspects of institution compatibility, economic viability, household acceptability, and technical feasibility. Such information is essential for a successful implementation of mitigation measures to effectively reduce arsenic contamination in drinking water. This manuscript presents findings from three related research projects which explored institutional, psychological, and technical factors which could enhance (or retard) the rate of arsenic mitigation in Bangladesh.

2. Arsenic mitigation: Institutional stakeholders perspective

There is no doubt that bringing tens of millions of people exposed to arsenic under safe water coverage is an immensely complex and expensive task. Therefore, understanding of this issue by institutional

Table 1
Alternative water supplies in arsenic-affected areas (excluding shallow tubewells) (DPHE/JICA, 2009).

Alternative water source	Number active	%	Population served per source	Estimated population served ('000)	%
Deep tubewells	164,652	91.2%	65	10,702	91.2%
Dug wells	9163	5.1%	40	367	3.1%
Pond sand filters	3431	1.9%	90	309	2.6%
Arsenic/iron removal plants	182	0.1%	65	12	0.1%
Rainwater harvesting systems	3045	1.7%	5	15	0.1%
Rural piped water schemes	134	0.1%	2500	335	2.9%
Total	180,607			11,740	

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