# Sustainable community- based safe water options to mitigate the Bangladesh arsenic catastrophe – An experience from two upazilas

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# Sustainable community-based safe water options to mitigate the Bangladesh arsenic catastrophe – An experience from two upazilas

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*Sustainable community-based safe water options have been successfully operating in two upazilas involving 531 villages and encompassing a population of 497,488. Testing of tubewells for arsenic was carried out on a census basis by trained village health workers (VHWs) using the Merck field-testing kit. A total of 51,685 tubewells were tested and further verified both in the field and laboratory. VHWs initially identified suspected arsenicosis patients who were later confirmed by physicians. A total of 403 patients were identified. The prevalence rates of arsenicosis were 106/10,000 in Sonargoan and 57/19,000 in Jhikargachha upazilas. The average age of the patients was 36 and 30 years respectively and the majority belong to the 15–45 years age group. There has been close community involvement at all stages of implementation of the arsenic-free safe water options adapted from various sources, giving preference to the community-based options to ensure local participation and utilize knowledge. Potential sources of arsenic-free drinking water were identified. To ensure sustainable use provided options were assessed based on community acceptability, technical viability, and financial viability. The key to the success of the project has been the combination of close integration with the community at all stages and appropriate technical solutions.*

MILLIONS in Bangladesh are facing poisoning from drinking arsenic-contaminated water[1,2]. Historically, surface water sources of Bangladesh have been contaminated, causing a significant burden of acute gastrointestinal diseases. To provide a presumably safe drinking water supply, millions of tubewells were dug in rural areas of Bangladesh. However, a major proportion of tubewells in Bangladesh have recently been found to be contamined with arsenic[3]. Arsenic contamination which was first confirmed in 1993 (ref. 4), now poses a major public health risk and provides a new threat in relation to the country's development. Investigators estimate that between 35 and 77 million of the 125 million inhabitants of Bangladesh are exposed to arsenic[5]. BRAC, one of the largest local non-governmental organizations in Bangladesh, has been involved in arsenic-mitigation activities since 1997. This action research project was carried out in two upazilas aiming at technical viability as well as effectiveness through determining the extent and level of arsenic contamination and acceptance of different safe water options. This paper presents the results of tubewell water testing and validation of testing, patient's identification and support, installation and monitoring and evaluation of safe water options in the two upazilas.

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## Materials and methods

Sonargaon and Jhikargachha were the two upazilas selected as project areas. Sonargaon is a low-lying area, which experiences flooding every year; in contrast, Jhikargachha experiences relatively low rainfall and is flood free. The total populations of Sonargaon and Jhikargachha were 261,881 and 235,607 respectively, living in 368 and 163 villages respectively.

As indicated in Figure 1, emphasis was placed on adopting a community-based approach, to ensure local participation and utilization of knowledge. After suitable training, village health workers (VHWs) were able to identify contaminated tubewells. After mapping resources in each of the project villages, community members were involved in selecting and implementing sources of arsenic-free drinking water. Multiple village meetings were held at different stages of the project to raise awareness, inform villagers, and most importantly

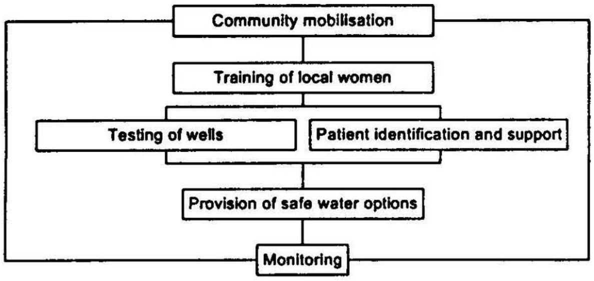


**Figure 1.** Flowchart of the BRAC arsenic mitigation programme.

involve villagers. At the meetings, demonstration units of various alternative safe-water options were supplied or installed, and the monitoring and maintenance of the alternative drinking water systems were discussed and the continued use of safe water use in the community promoted; water supplied from various alternative sources was monitored for arsenic, colliforms and other pollutants; and the acceptance of different mitigation strategies was evaluated.

Semi-illiterate local village women were selected as VHWs by BRAC. During a two-day-long training session at the BRAC offices, they were taught to perform the water testing, to identify suspected arsenicosis patients. The Merck field test kit was used to test water samples. One Merck field kit is capable of performing ca. 80 tests and costs around $50, giving an approximate price of $0.63 per test. The Merck kit uses a semi-quantitative colorimetric method, chemically converting arsenic present in the sample to arsine gas, which then colours a mercury bromide impregnated test paper, the colour change indicating the amount of arsenic present in the water sample. The field kit provides unreliable readings for arsenic concentrations between 10 and 100 μg/l. Accordingly, the following qualitative specification of tubewells was used: the spout of the tubewells was painted *green* denoting *safe* if the test paper was not stained (i.e. 0 μg/l), the spout was painted *red* indicating *dangerous* if the stain indicated a result equal to or above 100 μg/l (100 μg/l = 0.10 mg/l = 100 ppb). If the test paper showed some stain, i.e. greater than 0 but lower than 100 μg/l, the well was considered *potentially dangerous* and marked with a red cross on the spout.

VHWs primarily identified suspected arsenicosis patients when they made house-to-house visits to test for arsenic contamination in tubewell water, which were later confirmed by trained physicians. The different clinical manifestations and stages as described by Khan and Ahmad[6] were used to identify arsenicosis patients. Support was given to the patients by providing them with arsenic-free water along with different treatments (e.g. spirulina, vitamin A, C, E and salicylic acid).

## Safe water options

Three potential sources of arsenic-free drinking water were identified, namely treated surface water, rainwater and treated groundwater. Following this, different options using these sources were identified and chosen to be implemented during the project (Table 1). The options installed were assessed on several criteria and continuously monitored during the project period[6].

### *Pond and sand filters*

In areas where deep tubewells are not feasible, it is possible to treat surface water from ponds that are exclusively reserved for drinking purposes, to make it safe for drinking and cooking. A community-based slow sand filtration system, called *pond sand filter*, can remove bacteria from surface water by filtering it through a large tank filled with sand and gravel.

### *Rainwater harvesting*

Like pond sand filters, rainwater harvesting is already being introduced in arsenic-affected areas. The rainwater harvesting system uses a tin rooftop or sometimes a sheet of plastic, to collect rainwater and store it in large cement tanks. Users let the first few minutes of shower to clean roof and gutters without collecting the water. Once in the tank, the rainwater can be safely stored indefinitely without being contaminated by bacteria. With a large enough tank, a family can store enough water for drinking and cooking all through the dry season.

### *Dugwell*

Dugwells are an indigenous technology in Bangladesh. Use of dug wells has declined since the 1960s following the introduction of the shallow tubewells. The wells were cheaper and easier to construct and, most importantly, were less susceptible to bacteriological contamination.

Arsenic concentrations greater than the Bangladesh guideline of 50 ppb occur in moderately shallow aquifers in some areas in Bangladesh. The typical depth for arsenic occurrence is a narrow depth range 20–40 m below ground, the usual depth for the majority of tubewells. The ultra shallow (1–10 m) aquifer tends to have low arsenic concentrations. The British Geological Survey (BGS) 1998 suggests that within the zone of water table fluctuation (seasonal natural fluctuation) and where residence times are short, arsenic is being flushed away or immobilized. If dugwells are protected properly (i.e. lifting water by a hand tubewell, and by covering the top) they may also provide water of an acceptable bacteriological quality.

**Table 1.** Different safe water options initially selected for the project

| Option | Water sources | Location | Families served |
|---|---|---|---|
| Ponds sand filter (PSF) | Surface water | Community | 40–60 |
| Rainwater harvesting (RWH) | Rainwater | Family | 1 |
| Two chamber treated unit | Surface water | Community | 6–10 |
| Safi filter | Groundwater | Family | 1 |
| DPHE-DANIDA filter | Groundwater | Family | 1 |
| Three pitcher/three kolshi filter | Groundwater | Family | 1 |
| Home-based surface water filter | Surface water | Family | 1 |
| Arsenic removal plant (SIDKO) | Groundwater | Community | 50–75 |
| Tubewell sand filter (TSF) | Groundwater | Community | 20 |
| Activated alumina filter | Groundwater | Community | 30 |
| Motka | Rainwater | Family | 1 |

### *Monitoring of water quality and use of water*

Water quality of each of the alternate safe water options was monitored and tested, especially for diarrhoeal pathogen contamination. BRAC staff visited each village on a regular basis to monitor the operation and maintenance of alternative water systems and promote safe water use. After construction or distribution, continuous monitoring of the options is necessary at least for a few months because people are accustomed to using tubewell water and may find the alternative options more complicated.

## Results and discussions

### *Tubewell testing*

A total of 51,685 tubewells were tested in the two upazilas. As shown in Table 2, 62% tubewells in Sonargaon and 48% in Jhikargachha contained arsenic levels above 100 μg/l. In Sonargaon 12.5% of the tubewells tested green by VHWs were tested red by BRAC supervisors (false negatives) and 4% of the tubewells tested red by VHWs were tested green by BRAC supervisors (false positives). In Jhikargachha, 5% of the tubewells were found to be false negatives and 7% false positives. To validate the field testing performed by the VHWs, 5% of the total red and green marked tubewells of both upazilas were re-tested by BRAC field supervisors using identical Merck field test kits. A further 43 samples from 'green' tubewells were collected and analysed using atomic absorption spectrophotometer. To monitor any change in the results of the tubewell testing over time, tubewells tested 'green' in September 1999 with the Merck kit were re-tested in June 2000.

### *Characteristics of patients*

A total of 403 patients were identified in two upazilas. The characteristics of the arsenicosis patients were listed in Table 3. The prevalence was 106/10,000 in Sonargoan and 57/19,000 in Jhikargachha upazilas. The average age of the arsenicosis patients in Sonargoan and Jhikargachha was 36 and 30 years respectively, although the range was high (7–65 years in Sonargoan and 5–60 years in Jhikargachha). The majority of the patients were in the most active age group, between 15 and 45 (around 80% in Jhikargachha). It has been observed that socio-economic characteristics play an important role in accepting or implementing any new concept or ideas. From Table 3 it is observed that economic status of almost all the patients is found to be poor as only very few patients mentioned always having a surplus in their income–expenditure ratio (e.g. 5% and 19% respectively for Jhikargachha and Sonargaon upazilas). The gender difference of the affected population was found to be distinct. Patients in the Sonargaon upazila are more literate than those in Jhikargachha upazila (52% and 71% respectively). It has been observed that raising proper awareness creates an important role in motivating people about the disease. Therefore, initially it was found easier to motivate people of the Sonargaon upazila about arsenic and its mitigation efforts compared to Jhikargachha upazila.

### *Providing safe water options*

First priority for provision of safe water options was given to the identified patients, all of whom were provided with arsenic-free drinking water. Next in priority were villages where 50% or more of the tubewells were found contaminated (Table 2). In these 368 villages, poor families were prioritized in the distribution of home-based options, whereas community-based options were placed in areas where the majority of tubewells were found contaminated. As displayed in Table 4, almost a quarter of the population exposed to arsenic in their drinking water were provided with access to alternative safe water options. The assessment and monitoring of different safe water options showed that each had its individual strengths and limitations.

**Table 2.** Characteristics of arsenic contamination in two upazilas

| | Sonargaon | Jhikargachha |
|---|---|---|
| Total tubewells | 25,048 | 26,637 |
| Total dangerous tubewell, > 100 μg/l | 15,849 | 12,808 |
| Total potentially dangerous, 0–100 μg/l | 682 | 2850 |
| Safe, < 0 μg/l | 8877 | 10,979 |
| Total number of villages | 368 | 163 |
| 100% contaminated tubewells | 54 | 2 |
| 80% contaminated tubewells | 64 | 34 |
| 50% contaminated tubewells | 272 | 96 |

**Table 3.** Clinical characteristics of arsenic contamination in two upazilas

| Clinical characteristics | Sonargaon | Jhikargachha |
|---|---|---|
| Total population | 2,61,881 | 2,35,607 |
| Estimate population exposed, > 100 μg/l | 1,65,000 | 1,15,000 |
| Total number of patients | 252 | 151 |
| 1st stage | 170 | 107 |
| 2nd stage | 77 | 43 |
| 3rd stage | 5 | 1 |
| Average age | 36 | 30 |
| Affected male–female ratio | 1.5 : 1.0 | 1.5 : 1.0 |
| Education | | |
| Illiterate | 48% | 29% |
| Literate | 52% | 71% |
| Gender | | |
| Male | 63% | 62% |
| Female | 37% | 38% |
| Income–expenditure ratio | | |
| Always deficit | 46% | 12% |
| Always surplus | 11% | 19% |
| Balance | 14% | 50% |
| Sometimes deficit | 36% | 19% |

**Table 4.** Coverage by safe water options in two upazilas

| Total coverage | Sonargaon | Jhikargachha |
|---|---|---|
| No. of families covered by safe water options | 7750 | 4980 |
| % of families covered by safe water options | 23.5 | 21.7 |

An organized overall strategy to supply and monitor safe arsenic-free drinking water for the exposed population was one of the major objectives of the project. The first priority was given to the people who had been affected by arsenicosis. The next priority was given to villages where 50% or more tubewells were found to be contaminated with excess amount of arsenic. Based on these criteria, 368 out of 513 villages were listed for intervention to supply safe drinking water through different options. In selecting appropriate technical solutions it is important to know how these will function in the community. Strategies must be sustainable and community-based with recognition of the multidisciplinary nature of the problem. People were introduced to different safe water options, some of which were already known, while others were completely new to the people of the area. Potential sources of arsenic-free drinking water identified were (i) Treated pond and river water, (ii) Rain water, (iii) Dugwell, and (iv) Treated groundwater. The safe water options provided were assessed in terms of technical viability, community acceptability, and financial viability. The key to the success of the project has been the combination of close integration with the community at all stages and appropriate technical solution.

### *Are field methods needed for screening?*

In Bangladesh, laboratory-based methods to detect arsenic in water are available only in a few institutions and the cost is prohibitive. Several field-kit techniques are in use to detect arsenic and these are low cost and give rapid results, providing qualitative results (*Yes* or *No*) to be used for screening. If carefully controlled, the field kit procedure is a fairly reliable method. However, this is one main limitation of this study.

### *Distribution of patients*

A total of 403 arsenicosis patients were identified in cluster form, i.e. not evenly distributed across the affected areas, suggesting that other factors (e.g. nutritional status, diet, other social factors) were influencing the development and severity of arsenicosis. No correlation was apparent between the number of patients and arsenic contamination in the unions, although this was not examined for the individual tubewells. There is an urgent need for patient support and further research in Bangladesh. There are still many questions regarding the incidence of arsenicosis. Arsenic is a known carcinogen and it can produce various health effects in Bangladesh and elsewhere[7–11]. Anecdotal evidence suggests that after minimizing the level of contamination, a noteworthy declining trend was observed in West Bengal, India[12] and Samta village, Bangladesh, which concluded that recovery should be possible for the majority of arsenicosis patients[13].

### *Options limitation*

The options have been assessed on several criteria: initial and running costs, ease of implementation, operation and maintenance, continuity and flow of supply, arsenic removal capacity, sustainability of preventing bacteriological contamination and acceptability to the community (Table 5). Each of the options has its own strengths and limitations. BRAC has been able to provide safe water to

Table 5. Matrix to assess preference of the provided safe water options

| | PSF | RWH (old) | RWH (new) | Safi filter | Three pitcher filter | Surface water filter | SIDKO plant | Dugwell | TSF | Activated alumina filter |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial cost | 1 | 2 | 4 | 4 | 5 | 4 | 1 | 4 | 3 | 2 |
| Running costs | 4 | 5 | 5 | 3 | 2 | 5 | 1 | 5 | 5 | 1 |
| Ease of implementation | 1 | 1 | 2 | 5 | 4 | 4 | 1 | 5 | 2 | 3 |
| Technical effectiveness | 2 | 3 | 3 | 1 | 4 | 4 | 5 | 4 | 5 | 5 |
| Maintenance required? | 4 | 4 | 4 | 1 | 2 | 3 | 1 | 4 | 2 | 3 |
| Monitoring required? | 2 | 3 | 3 | 1 | 1 | 2 | 3 | 3 | 2 | 2 |
| Continuity of supply | 4 | 1 | 1 | 1 | 2 | 2 | 1 | 4 | 3 | 5 |
| Susceptibility to bacteriological contamination | 2 | 4 | 4 | 2 | 2 | 1 | 5 | 2 | 2 | 2 |
| Social acceptability | 1 | 1 | 1 | 3 | 3 | 1 | 3 | 5 | 4 | 4 |
| Total | 21 | 22 | 23 | 21 | 25 | 26 | 21 | 36 | 28 | 27 |

The matrix shows ratings of each of these factors on a scale of 1 to 5. The maximum possible is 45 and a higher rating indicates more potential.

nearly a quarter of the households exposed to arsenic contamination in all severely affected villages in the two upazilas. There is an abundance of surface water in Bangladesh, suggesting good potential for use of pond sand filters (PSF), which can fulfil the water needs of a large number of people. The original design was intended to serve 200 families. In reality, the distance which people would travel to fetch water means that only 40–60 families approximately could be served by a PSF. However, this is still a large number compared to other options. PSFs can be constructed with locally available materials and by local masons, once trained. There is no chemical treatment involved, so there is no risk of adverse health effects or damage to the environment. It can operate continually throughout the day and throughout the year. The prevalence of fish culture in most ponds in rural Bangladesh is a main limitation to PSF as herbicides. Other chemical fertilizers, cow dung, mustard cake, etc. are commonly used, making this water unsuitable for drinking purposes, even after treatment. Furthermore, farmers are reluctant to give up their ponds for PSF construction and thereby forego the income from fish culture.

The available surface water in Bangladesh is highly turbid in both dry and wet seasons: in the dry season, there is excessive growth of algae in pond and lake water, while in the wet season, rainwater drainage from the catchment area brings a lot of suspended sediment and makes the surface water highly turbid. Slow Sand Filter (SSF) does not work properly for high turbidities. Pond Sand filters operating on the principles of SSF in Bangladesh require frequent washing for high turbidities. Overall, Pond Sand Filters may be a good potential source of safe water for rural Bangladesh. However, sites for construction of this technology must be carefully chosen and local people must be committed to the correct use and maintenance of this option.

Considering the constraints of high cost and foreign technology, a modified system of rainwater harvesting is feasible at low cost, constructed with locally available materials. The capacity of this system was 515 l at a cost of approximately Tk.1, 800 (US$ 36). This model was used for the people during monsoon and was not intended for long-term storage; an additional option is required for the dry season.

Renovated/newly constructed dugwells might be another potential indigenous source of getting arsenic-free water for the exposed rural communities of the country. It has been observed that all the dugwells, so far renovated, were in operation both for cooking and drinking water purposes.

### *Future strategies*

A well-planned research programme is necessary for better understanding of the problem. Although the data concerning each type of option is fairly limited, an important result of the project has been the construction of these demonstration units. The awareness-building activities have helped raise the awareness level of the community about the arsenic problem and different mitigation options available. This project generated new knowledge on the provision of safe drinking water, their technical viability and community acceptance. Various sources of safe drinking water may be considered in future research[14,15]. Considering all aspects assessed in this project, the modified version of dugwells received the best rating, primarily because of their ease of use, low cost and simplicity.

## Conclusion

Several major lessons have been learned from the implementation of the action research project in the two upazilas of Bangladesh. With some training it is possible for female village volunteers to test tubewells for arsenic. However, the technology for testing needs further improvement. Volunteers can also be trained to preliminarily identify arsenicosis patients, develop awareness on the issue, the different alternative water supply options available and to monitor use of the option in the area. Local masons can be trained on the construction and manufacture of different options so that their expertise can be used to the maximum extent. Community mobilization and their involvement are essential for arsenic mitigation. People are willing to participate in testing, priority setting, awareness building, mitigation and cost sharing. Not all villages are affected equally and hence there is a need for prioritization during intervention. The feasibility, effectiveness, and acceptance of the safe water options available vary from place to place. All the options except dugwell, which is indigenous in nature, have been found to be either technically inefficient or disliked by communities for a number of reasons, such as, cumbersome process and monitory involvement in regular operation and maintenance of option, slow flow rate of treated water, low social acceptability, etc.

The technologies introduced in this project to supply arsenic-free safe drinking water are only short-term emergency solutions for areas severely affected by arsenic contamination. The long-term solutions must necessarily be based on a long-term vision. This may include the provision of piped water supply and the optimum use of surface water. The potential role that the local governments can play in the long-term vision must be fully explored. Towards this end, experimentation and pilot projects should not wait to mitigate this catastrophe.

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