TESTING OF TUBEWELL WATER OF THE COMMUNITY NUTRITION CENTRES (CNC) UNDER THE BANGLADESH INTEGRATED NUTRITION PROJECT (BINP) FOR PRESENCE OF ARSENIC

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Table of Contents

Executive Summary....4
Background....6
The arsenic problem elsewhere in the world....10
Strategy to mitigate the arsenic problem....13
Arsenic activities of BRAC....16
Objective of the study....17
Materials and methods....17
Specification of MERCK test kit....18
Results and discussions....19
Validation of field-testing results....21
Depth Vs arsenic contamination....21
Installation year Vs presence of arsenic in tubewell water....22
Average daily requirement of water by the CNC members....22
Drinking water sources of the CNC members at home....23
Options preferred by the arsenic-affected CNC members....24
Description of the alternative safe water option....24
Conclusion....37
Reference....38
Appendix....39
Sample questionnaire....43

List of tables

Table 1Basic statistics about Bangladesh and the arsenic problem..8
Table2 Qualitative and field specification of different levels of arsenic contamination............18
Table 3 Survey results at glance...19
Table 4 Validity of tubewell testing by field testers..21
Table 5 Drinking water sources at home of the CNC members...24
Table 6 Alternative options preferred by the arsenic affected CNC members.......................36

List of Figures

Figure1 Arsenic contaminated areas in Bangladesh...9
Figure2 Diagrammatic view to mitigate the arsenic problem 13
Figure3 Geographical distribution of the tested tubewells...20
Figure 4: Depth vs. Arsenic Contamination...21
Figure 4 Pond-sand-filter (PSF) 22
Figure 5: Installation year vs. presence of arsenic...23
Figure 6: Average daily requirement of water..25
Figure7 Rainwater harvester (RWH) 27
Figure 8 Safi filter 28
Figure9 Three-kolshi filter 30
Figure 10 Dugwell...31
Figure 11 ALCAN filter...33
Figure 12 Deep tubewell...35

EXECUTIVE SUMMARY

Bangladesh faces multi-faceted problems in relation to groundwater. At present there is a new threat - arsenic contamination in groundwater. Arsenic is a shiny, grey, brittle element possessing both metallic and non-metallic properties (Train, 1979). The source of arsenic in drinking water is geological. Arsenic occurs naturally in the sediments of Bangladesh bound to amorphous iron oxyhydroxide. However, there are lots of controversies over the origin of arsenic in the groundwater.

Bangladesh achieved remarkable success in providing safe drinking water to almost 97% of its rural population. But the recent discovery of arsenic in groundwater has ruined this decade-long success and the access to safe drinking water has now dropped to almost 80% (UNICEF, 1999). To mitigate the arsenic problem, a number of alternative safe water options are available in Bangladesh. Some of these options are based on surface water and some are based on treating the arsenic-contaminated water.

Malnutrition, which is a serious health concern in Bangladesh and poor socio-economic conditions aggravate the hazards of arsenic toxicity. The recent remarkable strides achieved in the health sector in Bangladesh have been slow down in the reduction of malnutrition (Jahan and Hossain, 1998). Fifty percent of the country's child mortality is reported to be associated directly or indirectly with malnutrition (BBS, 1994). The Bangladesh Integrated Nutrition Project (BINP) is the first major attempt of the government of Bangladesh to develop a comprehensive well-coordinated inter-sectoral programme financially supported by the World Bank (The World Bank, 1995).

Tubewell water is the only source of water for drinking and mixing the supplementary food at the CNCs for the pregnant women and children. Therefore, it is important to check tubewells of all the CNCs for presence of arsenic and subsequently to arrange alternative safe water options, if tubewell water is contaminated with arsenic at a dangerous level (i.e. >50μ/l). Accordingly, tubewell water of all the CNCs were tested with MERCK field testing kit and it was observed that only 26% tubewells found to be contaminated with arsenic more than the acceptable limit for Bangladesh. Unfortunately, it was observed that these contaminated tubewells were using for preparing food at the CNCs.

In order to develop the mitigation plan for the arsenic affected CNCs it is important to assess the average daily requirement of water by members of each CNCs to develop mitigation plans. It was observed that the daily requirement of water of almost all the CNCs was within the range of 20 litres per day, which means either small community-based option or household unit with good flow rate could be the suitable alternative safe water options for the arsenic affected CNCs.

An attempt was made to check the source of drinking water of the CNC members at their home, since they spend only a few hours at CNCs. It was observed that drinking water source of more than 80% CNC members at home is tubewell water and their arsenic status was not known the owners at the time of testing.

Focus group discussions were organized at the arsenic contaminated CNCs to get an idea about their preferred mitigation methods. Among the options preferred by the respondents deep hand set tubewell was found to be the most popular options (42%) followed by three-pitcher filters (25%). Since there is no curative measure for this disease except drinking arsenic-free water (Smith 2002), alternative suitable safe water options should be made available without any delay for the exposed pregnant women and children from further exposure to arsenic contaminated water.

BACKGROUND

Bangladesh faces multi-faceted problems in relation to groundwater. At present there is a new threat - arsenic contamination in groundwater. Arsenic is a shiny, grey, brittle element possessing both metallic and non-metallic properties (Train, 1979). Arsenic compounds are ubiquitous in nature, insoluble in water, and occur mostly as arsenides and arsenopyrites. Arsenic exists in the trivalent and pentavalent states in nature and its compounds may be either organic or inorganic. Trivalent inorganic arsenicals are more toxic than the pentavalent forms both to mammals and aquatic species. Though most forms of arsenic are toxic to humans, arsenicals have been used in the medical treatment of spirochaetal infections, blood dyscrasias, and dermatitis (Merck Index, 1968).

The degree of toxicity of arsenic depends on its chemical form and speciation. Humans are exposed to arsenic mainly through ingestion and inhalation. The World Health Organisation (WHO) has recently revised its original guideline value for arsenic in drinking water of 0.05mg/l (WHO, 1984) to a provisional guideline value of 0.01 mg/L (WHO, 1993). The Bangladeshi government level is 0.05 mg/l (DoE, 1991). Water with high levels of arsenic leads to health problems such as melanosis, leuko-melanosis, hyperkeratosis, black foot disease, cardiovascular disease, hepatomegaly, neuropathy and cancer (Khan and Ahmad 1997). Arsenic tends not to accumulate in the body but is excreted naturally. If ingested faster than it can be excreted, arsenic accumulates in the hair and fingernails (Khan, 1997). The toxicity of arsenic depends on the chemical and physical forms of the compound, the route by which it enters the body, the dose and the duration of exposure, dietary compositions of interacting elements and the age and sex of the exposed individuals.

There is a need to know more about the impact of arsenic poisoning on human health. For instance, there is no clear understanding of why some members of a family or community are affected, while others in the same family or community who are subject to the same contamination are not. Early symptoms of arsenic poisoning can range from the development of dark spots on the skin to a hardening of the skin into nodules - often on the palms and soles. The World Health Organization (WHO) estimates that these symptoms can take 5 to 10 years of constant exposure to arsenic to develop (DCH, 1997). Over time, these symptoms can become more pronounced and in some cases, internal organs including the liver, kidneys, and lungs can be affected. In the most severe of cases, cancer can develop in the skin and internal organs, and limbs can be affected by gangrene. While evidence exists that links arsenic to cancer, it is difficult to say how much exposure and for what period of time, will result in this disease.

The source of arsenic in drinking water is geological. Arsenic occurs naturally in the sediments of Bangladesh bound to amorphous iron oxyhydroxide. Due to the strongly reducing nature of groundwater in Bangladesh, this compound tends to break down and release arsenic into the groundwater (Nickson et al., 1998). Although arsenic occurs in alluvial sediments, its ultimate origin must be the outcrops of hard rocks higher up the Ganges catchment that were eroded in the recent geological past and then re-deposited in West Bengal and Bangladesh by the ancient courses of the Ganges. At present, these source rocks have not been identified. It is also important to understand that arsenic does not occur at all depths in the alluvial sediments. Although there is not enough evidence to draw firm conclusions, it appears that high concentrations of arsenic are restricted mainly to the shallow aquifer (less than 50 meters deep) (DPHE/BGS/DFID, 2000).

However, there are lots of controversies over the origin of arsenic in the groundwater. Indiscriminate use of agro-chemicals in the agricultural field for higher rice production and excessive use of groundwater for irrigation purposes *i.e.* oxidation process, are also some of the alternative hypotheses for the release of arsenic in groundwater. Therefore, it is very important to find out the exact cause in order to be able to implement different options.

Many organizations have implemented different arsenic programmes, most of which have focused on testing tubewell water for arsenic. The World Bank is taking the lead in co-ordinating an integrated response to the arsenic crisis and through the Government of Bangladesh is supporting the Bangladesh Arsenic-Mitigation Water Supply Project (BAMWSP). A key component of the BAMWSP will be the use of community-based, demand driven projects, in which community members play an active role in choosing and implementing solutions to the site-specific problems of arsenic contamination.

Until the early 1970s, more than 100 million inhabitants of Bangladesh and neighbouring West Bengal drank from shallow hand-dug wells, rivers and ponds. But pollution was causing epidemics of diarrhoea, aemebiasis, polio, typhoid and other water-borne diseases. This persuaded aid agencies such as UNICEF and others to spend tens of millions of pounds sinking tubewells - steel pipes fitted with simple hand pumps- to tap the plentiful and apparently clean water in the sand and silt of the Ganges flood plain. Following this example, the rural people of Bangladesh later sank many more tubewells privately. The number of tubewells present today is estimated between 6-10 million whereas it was only about 50,000 during the British colonial rule (UNICEF 1999). But the recent discovery of arsenic in groundwater has ruined this decade-long success and the access to safe drinking water has now dropped to almost 80% (UNICEF, 1999). Collin Devis, Chief of Water and Environmental Sanitation of UNICEF rightly mentions that Bangladesh has become the victim of its own success (Independent, 2000). Therefore, it is very important that any environmental policy be developed according to proper scientific and socio-economic foundations otherwise things may go wrong at a tremendous expense without achieving any gain (Trudgill, 1990).

The following table gives some basic statistics about the severity of the arsenic problem:

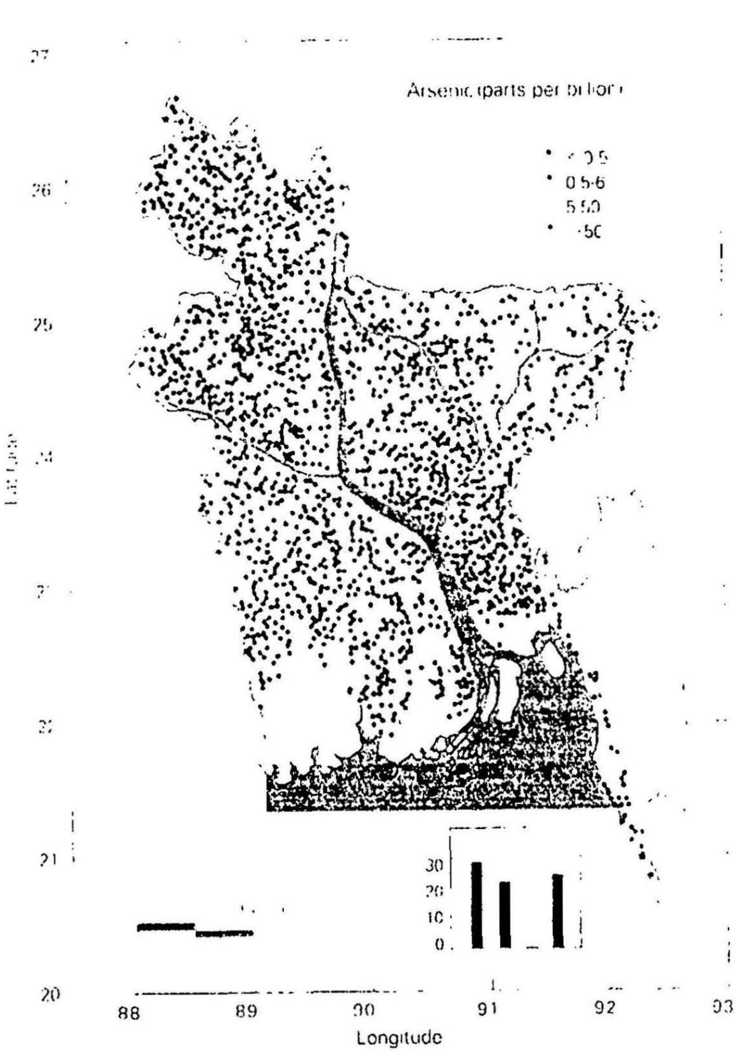
Table 1: Basic statistics about Bangladesh and the Arsenic Problem

Number of total districts	64
Total area of Bangladesh	148,393 km^2.
Number of total population	120 million
GDP per capita (1998)	US$ 260
Drinking water standard for arsenic (WHO)	0.01mg/l
Drinking water standard for arsenic (Bangladesh)	0.05 mg/l
Number of districts surveyed for arsenic concentration	64
No. of districts having arsenic above maximum permissible limit	59
Population at risk of the affected districts	75 million
Potentially exposed population	24 million
Number of patients suffering from arsenocosis	7000-10,000
Total number of tubewells	3-4 million
Total number of affected tubewells	1.12 million

Source: ACIC, 1998

Apart from the health concern indicated in the table, a number of social problems are associated with this hazard that have far-reaching consequences for millions of rural people. The problem is intensified when we observe that the distribution of arsenic in groundwater is not uniform throughout the country – that is if one tubewell is contaminated with arsenic the next tubewell (that may be a few hundred meters away) is not necessarily also contaminated. Therefore, blanket testing of all the existing hand-tubewells of Bangladesh and simultaneous provision of alternative safe water options to the affected communities are the topmost priorities in order to alleviate the problem (see Figure 1 for the distribution of arsenic in the groundwater of Bangladesh).

Figure 1: Arsenic contaminated areas in Bangladesh



Groundwater Studies of Arsenic Contamination in Bangladesh DPHE/BGS/DFID (2000)

THE ARSENIC PROBLEM ELSEWHERE IN THE WORLD

Arsenic contamination is not unique to Bangladesh. Highly elevated levels of arsenic of natural origin have been reported in groundwater in many parts of the world. Arsenic poisoning due to excessive exposure to natural and anthropogenic arsenic in drinking water has been reported in Argentina, China, Taiwan, Thailand, India, Mexico, USA, Ghana, Hungary, United Kingdom, Chile, New Zealand, and Russia (CSIRO, 1999). The following are brief descriptions of the arsenic problem in each of these countries:

Argentina

In Argentina, groundwater arsenic concentration in some places ranges from 100 to 2000 microgram/l. Reports from epidemiological studies in Argentina indicated that 0.3mg/l arsenic in drinking water resulted in increased incidences of hyperkeratosis and skin cancer with an increased consumption of water (Trelles, et al., 1970).

China

According to a survey carried out in some parts of China, the main sources of arsenic poisoning in drinking water are deep wells in basin areas rather than shallow hand tubewells. The arsenic concentrations range as high as 0.6 to 1.2 mg/l. The epidemiological data demonstrated the evident association of arsenic poisoning with the arsenic concentration in drinking water (Nie et al., 1997).

Thailand

The sources of arsenic contamination of groundwater in Thailand are high-grade arsenopyrite waste piles and alluvial mineral deposits. In some parts of Thailand shallow tubewells were found to be contaminated with arsenic at concentrations of more than 5mg/l but the deeper aquifer was less contaminated (Fordyce et al., 1995).

Taiwan

In Taiwan the groundwater arsenic problem was reported as early as 1968 and a large number of people suffered from arsenical dermatosis. They gave arsenicosis the name 'black-foot disease'.

Arsenic concentrations in the tubewells ranged from 10 to 1820 microgram/litre, and 19% of the wells had arsenic levels of over 50 microgram/litre (Hsu et al., 1997).

West Bengal

Six districts of West Bengal including 466 village and many municipal areas were found to be contaminated with arsenic. About one million people were drinking arsenic-contaminated water and about 200,000 people already showed the symptom of arsenical skin lesions (Das et al., 1996).

USA

The sources of arsenic in well water in Nevada, Arizona and California are geological, though the nature of the arsenic-enriched deposits is as yet unknown. In Nevada, elevated concentrations of arsenic occur in several groundwater basins, and five community water systems exceed the current 0.05mg/l standard for the USA (Fontaine, 1994).

Mexico

In some parts of northern Mexico, chronic arsenic poisoning is endemic, leading to changes in skin pigmentation, keratosis, skin cancer, black-foot disease and gastro-intestinal problems. An average concentration of 0.4 mg/l of arsenic was recorded in some parts of northern Mexico (Del Razo et al., 1994). The source of arsenic was assumed to be geological.

Hungary

In the south-eastern part of Hungary, drinking water wells were contaminated with arsenic in concentrations high enough to pose long term health hazard to about 0.4 million people. Arsenic pollution in Hungary was believed to spread due to the use of pesticides containing arsenic (Halvay, 1988).

United Kingdom

Arsenic levels higher than the current Environmental Protection Agency standard have been discovered in private wells in New England, New Hampshire, Cornwall. A study of arsenic in surface waters in Cornwall has shown soluble arsenic in specific catchments to range from 10 to

50 microgram/l (Aston et al., 1975). However, extraction of surface water for processing and distribution avoids water contaminated by past mining activities, and water processing using aluminium hydroxide removes the majority of the soluble arsenic. As a result arsenic in drinking water in Cornwall rarely exceeds 10 microgram/l (MAFF, 1982).

Chile

Chronic arsenic poisoning has been reported in a population exposed to elevated concentrations of arsenic in surface waters (rivers, creeks, lakes, etc.) used for drinking water and irrigation purposes. The sources of the arsenic have been reported as being volcanic sediments, minerals and soils (Carceres et al., 1992). Dermatological manifestations of arsenicism were noted in children in Antofagasta, Chile who used a water supply containing an arsenic concentration of 0.8 mg/l (Borgonno and Grieber, 1972).

A STRATEGY TO MITIGATE THE ARSENIC PROBLEM

Following is a diagrammatic representation of a strategy to mitigate the impact of arsenic problem of Bangladesh:

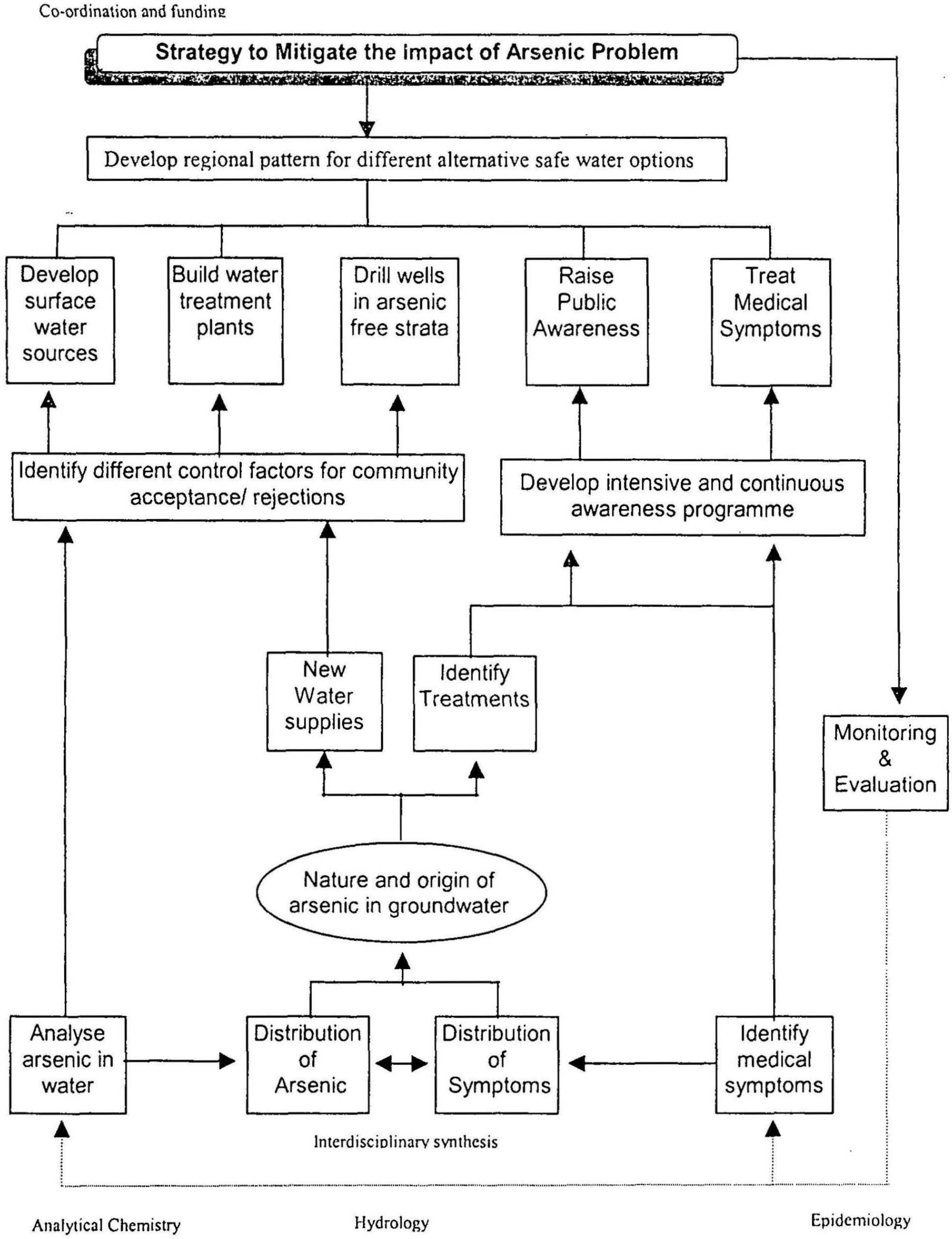


Figure 2: Diagrammatic view to mitigate the arsenic problem (modified from BEN, 1997)

It is to be observed from the above diagram that the whole arsenic scenario in Bangladesh can be divided into the following major categories:

- **Development of a regional arsenic mitigation plan**

It has already been proved that not all the available options are suitable for every place. Physio-cultural and socio-economic variation among communities played a dominant role for accepting or rejecting a particular option by communities. For example, in some area surface water treatment unit might be the only possible method of treating arsenic contaminated water than other areas where treating arsenic contaminated might prove the only possible method of treating arsenic contaminated water. Therefore, considering the present circumstances, a well-designed study is urgently needed in order to develop a suitable countrywide alternative safe water option package for the sustainable implementation of the arsenic mitigation activities in Bangladesh.

- **Co-ordination and funding**

This is one of the most important components. Co-ordination is needed among different stakeholders not only to avoid repetition of activities but also to find a mitigation package that is acceptable to the community. Apart from that funding is crucial to run different research activities related to the problem.

- **Hydrology**

This is also an important component. Until and unless the exact causes of arsenic contamination in the groundwater are identified it is very difficult to develop a standard community-acceptable mitigation package.

- **Analytical chemistry**

It is very important to develop a system of arsenic detection in tubewell water that the community can operate themselves; this would minimise the expenses incurred in testing by outside experts.

- **Water supply and engineering**

Safe drinking water also has to be community-acceptable and affordable. At the same time it is also important to make available different types of mitigation options for different type of communities and for different physiographic conditions. Therefore, the involvement of community in the selection, implementation, operation and maintenance of a system is crucial.

- **Epidemiology or Public Health**

Drinking arsenic-free water is currently the only way of preventing the disease. Therefore, it is very important to develop a strong awareness programme in order to motivate people in the rural communities to drink water from arsenic-free sources. At the same time, it is very important to do further research aimed at finding a proper treatment for the disease.

- **Monitoring and evaluation**

The continuous monitoring of the presence of arsenic in tubewell water is essential: the arsenic level varies seasonally, therefore it is important to check each tubewell at least once every six months. At the same time monitoring the performance of the provided options is also important. It will be both cost-effective and convenient if communities are trained to carry out these activities themselves.

It has been observed from the above discussion that except for the geological investigation of the causes of arsenic contamination, the active presence of the community in all other activities is crucial for the sustainable implementation of the arsenic mitigation activities in the rural areas of Bangladesh.

Since almost all the provided alternative safe water options are new both to the experts and the community, proper consultation and ensured co-operation from the community are pre-requisites for the establishment of a safe water implementation plan. The importance of identifying different factors for community participation in the various alternative safe water options can be observed from the figure. The community needs to consult during different phases of project implementation, i.e. from the selection of options to the monitoring and evaluation of a particular option.

As regards manifestation in a person's body, the symptoms of arsenic toxicity may take several months to several years. This period differs from person to person, depending on the quantity and volume of arsenic ingested, nutritional status of the person, immunity level of the individual and the total time period of arsenic ingestion (DCH, 1997). Malnutrition and poor socio-economic conditions aggravate the hazards of arsenic toxicity.

The recent remarkable strides achieved in the health sector in Bangladesh have been slow down in the reduction of malnutrition (Jahan and Hossain, 1998). Fifty percent of the country's child mortality is reported to be associated directly or indirectly with malnutrition (BBS, 1994). The Bangladesh Integrated Nutrition Project (BINP) is the first major attempt of the government of Bangladesh to develop a comprehensive well-coordinated inter-sectoral programme financially supported by the World Bank (The World Bank, 1995). Initiated in 1996, the ultimate goal of the project is to reduce the maternal and child malnutrition in Bangladesh to the extent that it ceases to be a public health problem. Community-based Nutrition Component (CBNC) is one of the three major components of the project implemented jointly by the government and NGOs under which children (<2 years), pregnant and lactating women are provided with supplementary food at the Community Nutrition Centres (CNC).

Tubewell water is the only source of water for drinking and mixing the supplementary food at the CNCs. The recent discovery of arsenic in tubewell water in Bangladesh, which has potential public health hazards, is a matter of grave concern. This is particularly concern for the CNCs because the main source of preparing the supplementary food is tubewell water. Therefore, it is important to check tubewells of all the CNCs for presence of arsenic of all the CNCs and subsequently to arrange alternative safe water options, if tubewell water is contaminated with arsenic at a dangerous level.

ARSENIC ACTIVITIES OF BRAC

BRAC, one of the largest national non-governmental organisations, has a proven capacity in field-level programme implementation, research, institutional networking and experience in training of community members in testing tubewell water for arsenic. BRAC has been active in the field of arsenic since 1997 starting with testing all the 802 tubewells in its field offices. Later, in early 1998, BRAC tested each and every tubewells of Hajiganj upazila. The situation in Hajiganj was found to be quite alarming; of all of 11,954 tubewells tested 93% showed the presence of arsenic.

In June 1998, BRAC completed a countrywide testing of tubewells, which were installed by the Department of Public Health Engineering (DPHE) of the government during 1997-1998 with assistance from UNICEF. A total of 12,604 tubewells were tested under this project using field kits. It took about 35 days to complete the testing which again confirmed the effectiveness of the methodology used by BRAC in carrying out arsenic testing.

In 1999 BRAC, in collaboration with UNICEF and DPHE, initiated a pilot project on community-based arsenic mitigation in one union of Sonargaon upazila under Narayanganj district. This study aimed to find out the success and constraints in implementing such a project completely new in the country. In June 1999, BRAC extended the action research to another upazila - Jhikargacha of Jessore district. Working closely with DPHE/UNICEF, it actively involves communities in assessing and mitigating the arsenic crisis. Later, in the same year BRAC extended the same project in four more upazilas. Currently, BRAC is expanding its arsenic programme in another two severely affected areas of Bangladesh with support from DHPE/UICEF.

OBJECTIVES OF THE STUDY

The objectives of the study were to assess the presence of arsenic in tubewell water of CNCs; to assess the daily water requirement of the CNC members and finally to develop mitigation plan for the arsenic contaminated CNCs.

MATERIALS AND METHODS

Presence of arsenic in tubewell water was being carried out with the help of a group of trained enumerator who were previously involved in a countrywide arsenic testing programme of BRAC. New MERCK field-testing kit (approved by the technical advisory committee of

BAMWSP) was used to carry out the testing programme. To comply with the guidelines of the Technical Advisory Group (TAG) of the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), it was decided to use Merck field-testing kit of Germany. The Merck kit uses a semi-quantitative colourometric method. Addition of chemicals to the water sample converts the arsenic present in water to arsine gas, which then reacts with a mercury bromide impregnated test paper. The change of colour on the paper indicates the amount of arsenic present in the water sample.

If the test paper shows no stain and stain produced equal to 50µ/L or below then these wells are considered 'safe' and are marked 'green'. If it shows a stain greater than 50µ/L they are considered 'dangerous' and are marked 'red'. Table 2 shows the definition of arsenic contamination and their qualitative and field specification.

Specification of Merck test kit

Table 2 Qualitative and field specification of different levels of arsenic contamination.

Level of arsenic 50µ/L	Qualitative specification	Spout of TW painted
0	Safe	Green
10	Safe	Green
25	Safe	Green
50+	Dangerous	Red

The enumerators who carried out the testing were given a tow-day orientation on the new testing methods. Field supervisors re-tested about 3% of the total tubewell water tested by the supervisors.

Because of shortage of funds laboratory analysis of the water samples could not be performed.

Focus group discussion was carried out to develop mitigation plans for the arsenic-affected CNCs. A questionnaire survey was carried out at each CNC to understand the water availability and the water use pattern to develop a package for possible mitigation measures.

RESULTS AND DISCUSSIONS

The study was conducted in 40 BINP (Bangladesh Integrated Nutrition Project) operated upazilas of Bangladesh. The number of community nutrition organization (CNO) under these upazilas was 1,328, and the number of CNCs, which was equivalent to the number of total tubewells in the area, was about 7,782 (see Annex for detailed test results). Table 3 shows that concentration of arsenic level in 26% of the tested tubewell water were found to be contaminated with arsenic more than the acceptable limit for Bangladesh (i.e. more than 50µ/L). Unfortunately, it was observed that these contaminated tubewells were using for preparing food at the CNCs.

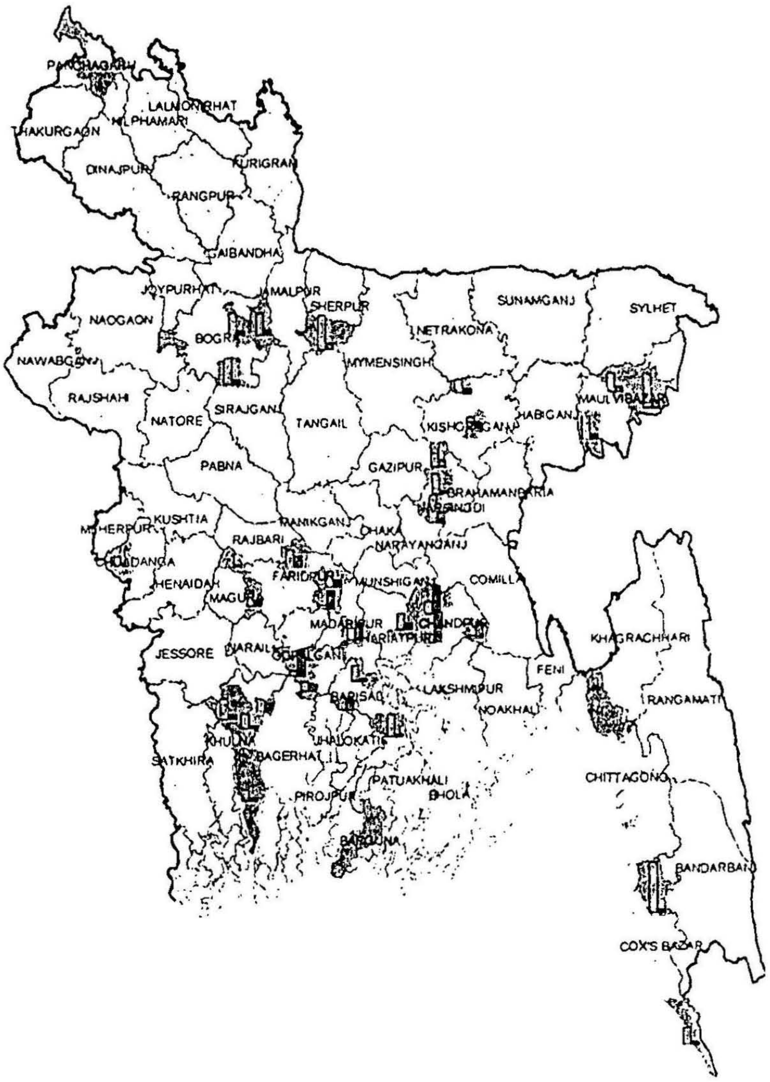
Table 3: Survey results at a glance

Total number of upazilas:	40
Total number of CNCs:	8,002
Total number of tubewell water tested for arsenic:	7782
As-free:	5720 (74%)
Number of inactive/ not in use tubewells:	143 (2%)
Tubewell water not tested for arsenic (in Matlab):	77 (1%)

Figures within parentheses indicate percentage

Less than 2% tubewell were not in operation at the time of testing tubewell water of the CNCs. A majority of this type of tubewell were not in operation due presence of arsenic and the CNC members were collecting water from the nearest arsenic-free safe water sources while on the other hand, few tubewells were non-functional during the testing period. It was not possible to test water of 77 tubwells at Matlab upazila where BRAC jointly with ICDDR,B has started an arsenic mitigation and epidemiological study. As part of the study process all the tubewell water under this project will be tested after the identification of arsenicocsis patients. This will be done to make the patient identification process non-biased with tubewell testing results. Therefore, it was agreed that water of these tubewells will be tested by the BRAC-ICDDR,B water testing team. The geographical distribution of the tested tubewells is presented in Figure 3.

Figure 3: Geographical distribution of the tested tubewells



VALIDATION OF FIELD-TESTING RESULTS

To check the accuracy of arsenic testing by the field testers the water of 233 tubewells were re-tested by the filed supervisors using the same MERC field test kit. Table 4 shows that the field testers correctly tested the tubewell water.

Table 4: Validity of tubewell testing by field testers

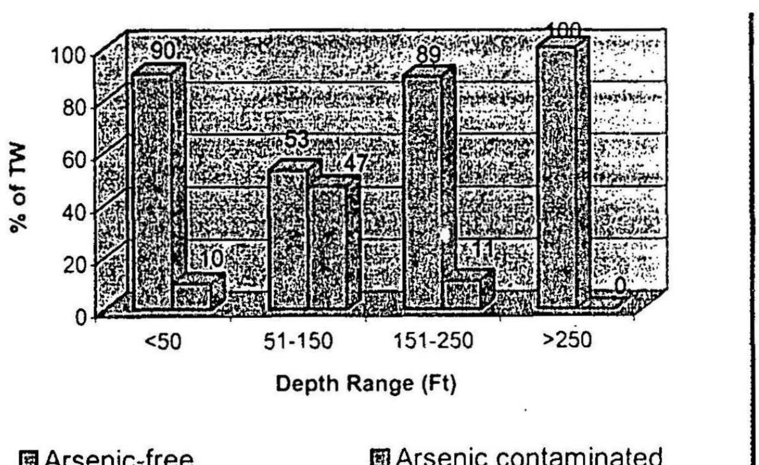
Tested by field testers	Re-tested by supervisors		Total
	Red	Green	
Red	213	0	213 (100%)
Green	0	20	20 (100%)

Figures within parentheses indicate percentage

DEPTH VS. ARSENIC CONTAMINATION

Figure 4 shows that the presence of arsenic is very few in the depth less than 50 ft and this concentration is totally absent from the depth >250 feet. The major concentration of arsenic (47%) is observed in the range of 51-150 feet depth. This trend of arsenic concentration at various depths is almost similar to the findings of the other surveys (BGS 2000).

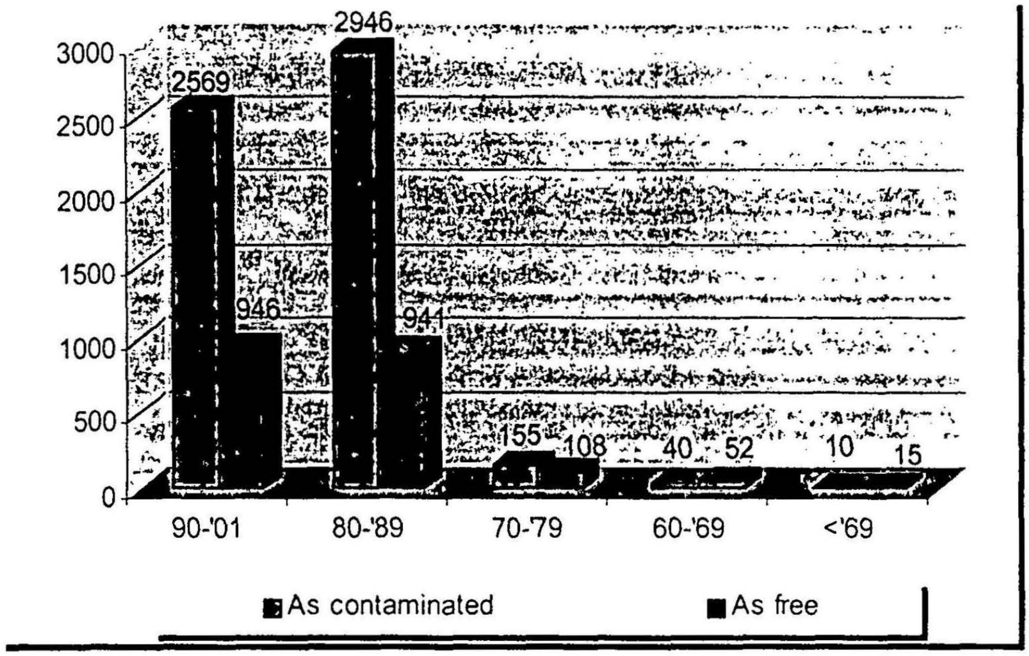
Figure 4: Depth vs. Arsenic Contamination



INSTALLATION YEAR VS. PRESENCE OF ARSENIC IN TUBEWELL WATER

More than 95% of the total tubewells installed during the last 20 years; that means mass level installation of hand tubewell is a recent phenomena (Figure 5). Percentage of arsenic concentration is comparatively higher in the recently installed tubewells, which is, to some extent, contradictory to other findings (BGS 2001), where they discovered that arsenic contamination was high in the older tubewells. However, this needs further investigation.

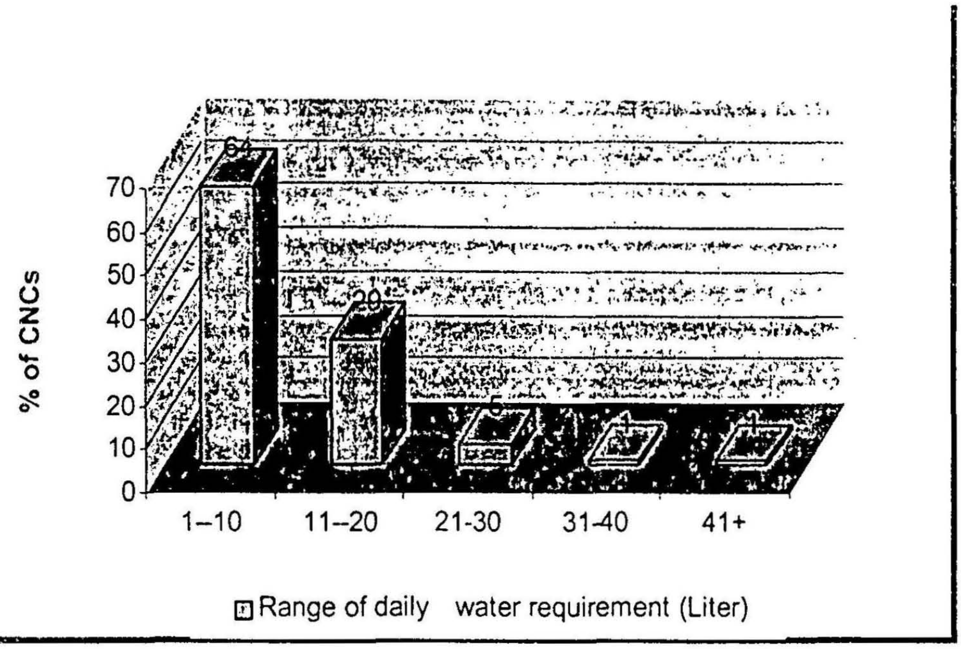
Figure 5: Installation year vs. presence of arsenic



AVERAGE DAILY REQUIREMENT OF WATER BY THE CNC MEMBERS

It is important to assess the average daily requirement of water by CNC members to develop mitigation plans. Figure 6 shows that the maximum daily water requirement in more than 72% CNCs is up to 20 litres, which means either small community-based option or household unit with good flow rate could be the suitable alternative safe water options for the arsenic affected CNCs.

Figure 6: Average daily requirement of water



DRINKING WATER SOURCES OF THE CNC MEMBERS AT HOME

Since the villagers stay for short time in the CNCs, it is important to know the sources of drinking water at their homes. Table 5 shows that 82% of the villagers were drinking tubewell water. Their arsenic status could not be collected at the time of testing. The villagers were seen collecting their drinking water from a wide range of options. In most case they were doing practicing these new option to get rid of the arsenic problem.

Table 5: **Drinking water sources at home of some of the CNC members**

Source of drinking water	No. of respondents
Tubewell	7217 (81.63)
Deep tubewell	810 (9.16)
Boiled/purified river/pond/canal water	474 (5.36)
Dugwell	132 (1.49)
Spring water	94 (1.06)
Iron removal filter	51 (0.58)
Pond-sand filter	44 (0.50)
Supply water	11 (0.12)
Rainwater	8 (0.1)
Total	**8,841**

Figures within parentheses indicate percentage

ALTERNATIVE OPTIONS PREFERRED

Focus group discussions were organized at the arsenic contaminated CNCs to get an idea about their preferred mitigation methods. CNC members were given adequate knowledge about different available mitigation options and later they were asked to mention their preferred mitigation method. Brief description of the available mitigation options is presented below:

Description of the alternative safe water options

Three potential sources of arsenic-free drinking water were identified, namely treated surface water, rainwater and treated groundwater. Description of each type of unit is given below:

1. Pond Sand Filter (PSF)

Filtration is the process by which water is purified by passing it through a porous media. In slow sand filtration a bed of fine sand is used through which the water slowly percolates downward. The suspended matter present in the raw water is largely retained in the upper 0.5-2 cm of the filter bed. This allows the filter to be cleaned by scraping away the top layer of sand. The filter cleaning operation need not take more than one day, but after cleaning one or two more days are required for the filter bed to again become fully effective.

In the coastal belt of Bangladesh where much of the groundwater is salted, the local population is dependent on surface water from dug ponds. Since the untreated water from these ponds is unpotable DPHE with funding from UNICEF have installed slow sand filtration units into which pond water is fed using a handpump. These units are called Pond Sand Filters (PSF) (Figure 7). The use of PSF technology to filter surface water is also considered appropriate for areas where groundwater is contaminated with arsenic. One pond sand filter can supply the daily requirement of drinking and cooking water for about 40-60 families.

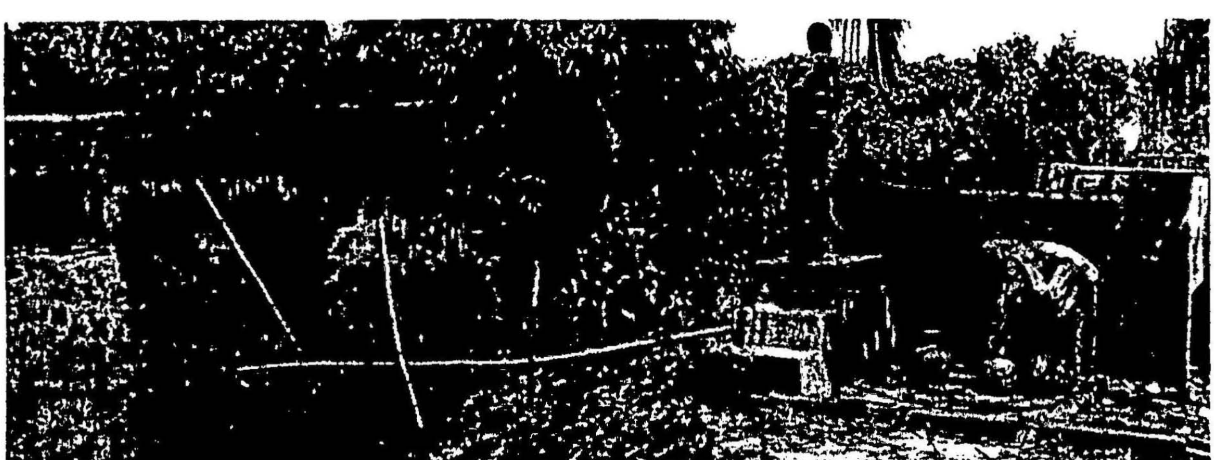


Figure 7: Pond Sand Filter

Availability of large numbers of perennial waterbodies seemed initially to be a strong point in favour of constructing PSFs in the project areas. However, it was found later that many of these water bodies were in use for commercial fish culture, which made them unsuitable for human consumption.

Generally it seems that PSFs can reduce the level of bacteria in water by an order of two. The level of coliform bacteria in many of the ponds of Bangladesh is so high that even after treatment by a PSF the water will not be completely bacteria free.

PSFs can be constructed with locally available materials and by local masons once trained. There is no chemical treatment involved, so no risk of adverse health effects or damage to the environment.

Availability of large numbers of perennial waterbodies seemed initially to be a strong point in favour of constructing PSFs in the project areas. However, it was found later that many of these water bodies were in use for commercial fish culture. Some fish farmers use highly toxic chemicals such as aldrin/dieldrin to kill predator fish before releasing fish fry. They also put different chemical fertilisers, cow dung, mustard cake etc. into the pond as fish feed. Clearly the water from such ponds is not suitable for use as drinking water even after treatment.

Generally it seems that PSFs can reduce the level of bacteria in water by an order of two. The level of coliform bacteria in many of the ponds of Bangladesh is so high that even after treatment by a PSF the water will not be completely bacteria free.

The PSF users often complained that PSF water tasted foul. The taste of PSF water was obviously different from the tubewell water to which they were used to. For this reason many people were found using this water only for cooking purposes and very few are using this for drinking purposes.

Overall, Pond Sand Filters may be good potential source of safe water for rural Bangladesh. However, sites for construction of this technology must be carefully chosen and local people must commit to proper use and maintenance of this option.

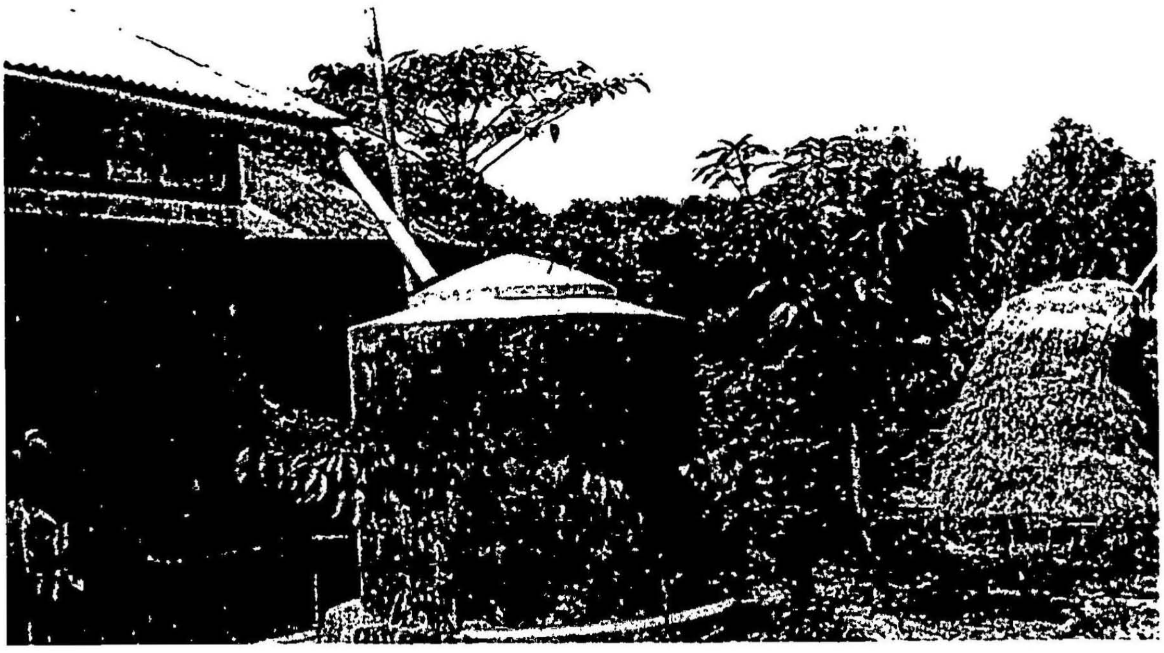
2. Rain Water Harvester (RWH)

Rainwater harvesting is practiced in many parts of the world. For example, there is a long tradition of rainwater collection in some parts of Alaska and Hawaii in the USA The city of Austin, Texas, offers a rebate for using rainwater. The island of Gibraltar has one of the largest rainwater collection systems in existence. Rainwater harvesting is also popular in Kenya, South Africa, Botswana, Tanzania, Sri Lanka, Thailand (Daily Star, 24 Sep. 1999).

In some areas of Bangladesh the potential for rainwater harvesting is good. However, rainfall is variable across the country. Mean annual precipitation of Bangladesh ranges from 1,400 mm (about 55 inches) along the country's east central border to more than 5,000 mm (200 inches) in the far north-east (Rashid, 1977). The wet months of monsoon from mid June to late September have 80% of the annual precipitation.

3,200 litre RWH is constructed using pre-cast concrete blocks and the total construction cost is about Tk 8,000 (Figure 8). It was observed that although people were happy with the quality of the water the cost was prohibitive for many rural households, since as it only provides a partial solution.

Figure 8: Rainwater Harvester



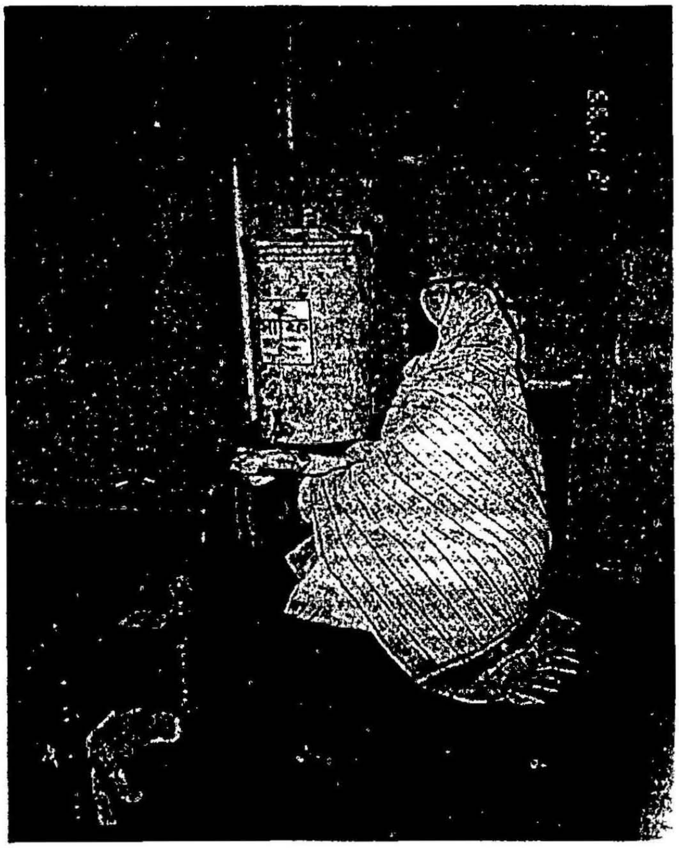
Also in every case, the RWH was used by more than one family so the water only lasted for a limited period (maximum one month), not long enough to cover the full dry period.

Analysis for total coliform and faecal coliform bacteria to assess the safety level of the RWH water for drinking was done at laboratory and the results were found to be highly satisfactory (BRAC 2000).

3. *Safi Filter*

This household level filtration device developed locally by Professor Sayeed Safiullah of Jahangirnagar University works by filtering arsenic out of contaminated water. This device is known as "Safi filter". One small Safi filter is designed to filter approximately 40 litres of water per day (Fig. 5.11). This should be more than sufficient for the needs of a family of six. The cost of such filter is Tk. 900. Larger filters for schools and other community -- use are available which can filter 80 litres of water per day at a cost of Tk. 2,000 (Figure 9).

Figure 9: Safi Filter



The Safi filter comprises of two concrete buckets of different sizes, one of which is placed inside the other. The upper bucket is filled with tubewell water which then flows through a permeable 'candle' and is collected in the lower bucket where it is stored. When needed it is drawn off with a tap.

The Safi filter was designed to remove both arsenic and pathogenic bacteria. The Safi candles distributed initially had lots of problems in terms of flow rate and arsenic removal efficiency (BRAC Report 2000). The candles distributed later have overcome all these problems and now it is giving constant good results for a reasonably long period of time. The cost of a new candle is Tk. 600 and another couple of Taka will be needed to regenerate the candle life for every two years.

4. Three-kolshi or three-pitcher filter

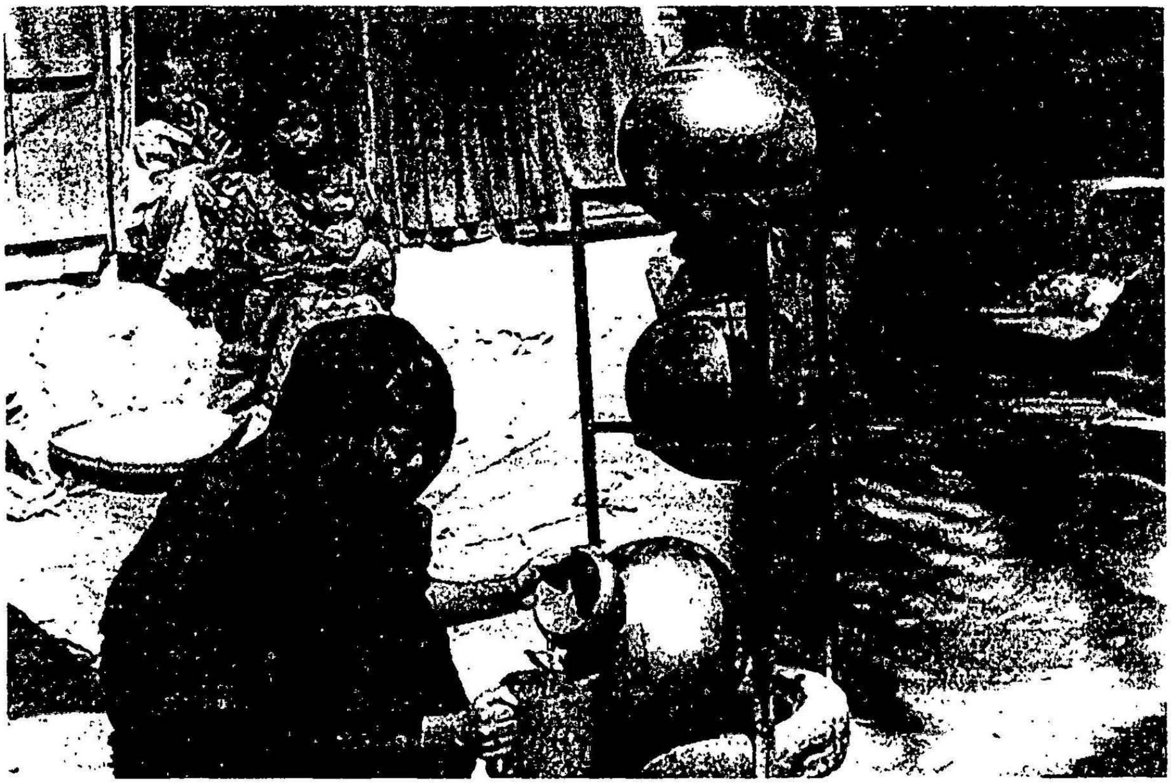
The three-pitcher filter is based on an indigenous method of filtration which has been used in Bangladesh for ages. Local clay pitcher (called kolshi) is partially filled with sand and charcoal, and a small hole is made in the bottom of the pitchers. A piece of synthetic cloth is placed over the whole to prevent sand from spilling out.

Water is passed through this pitcher to remove suspended matter from surface water and more recently to remove iron from tubewell water (Figure 10). Scientists from Bangladesh and the USA noted the potential of this simple method to remove arsenic as well. They modified the system by adding iron filings to provide an additional source of iron oxide to adsorb more arsenic (Rasul et al, 1999).

The three-pitcher system has enormous potential to provide an emergency drinking water source for the arsenic-affected areas in rural Bangladesh. It is based on an indigenous technology, is inexpensive, and can be constructed with locally available materials. Cultural acceptance is high.

There are, however, a number of unanswered questions about the three pitcher filters which need to be addressed before it is taken up on a larger scale. First, it appears from our results that bacteriological contamination of the water is occurring before or during filtration. If this happen

Figure 10: Three-*pitcher* Filter



during filtration then all filter materials must be sterilised before the manufacture of the filter. It may be possible to do this by heating under the sun or boiling in water. Experiments are currently underway to overcome the problem of microbial contamination with the three pitcher filters.

It has not been proven beyond doubt that the water from the three-pitcher filter will be completely free of chemical impurities. The potential for trace elements such as lead, chromium, zinc, tin, etc. to enter the water from the iron filings must be conclusively discounted.

The final question about the three-pitcher filter is whether it is technically effective in the long run. Five months of continuous monitoring revealed that after four months the filters start leaching arsenic. Also it becomes clogged with iron and must be cleaned; for future use, a cleaning or regeneration process needs to be designed. There are some initial reports that the layer of iron filings forms into a hard mass over time. This must be investigated and the potential for channeling of water through the iron filings, and thus leakage of arsenic through the system, determined.

The three-pitcher filter is inexpensive. One filter can be made for around Tk. 250. Of this, Tk. 170 is for metal frame, Tk. 30 is for the three clay pitchers and the Tk. 50 for sand, iron filings and charcoal. BRAC field staff experimented with wooden and bamboo frames to minimise the cost. However, the price difference was not enough to merit their use in large scale.

5. Dugwells

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.

Figure 11: Improved hygiene dugwell

Arsenic concentrations greater than the Bangladesh guideline of 50 ppb occur in moderately shallow aquifers in some areas in Bangladesh. Typical depths for arsenic occurrence is a narrow depth range of 20-40 metres below ground, the usual depth for the majority of tubewells. The ultra shallow (1-10m) aquifer tends to have low arsenic concentrations.

The British Geological Survey (BGS) 1998 suggests that within the zone of water table fluctuation (season 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.

Dugwells have been constructed by following the design of 'converted hand-pumped dug well' given in WHO Guidelines for Drinking Water Quality Vol. 3 (1997). The wells are covered and water is drawn from the well using a hand pump (Figure 8). An apron is constructed around the well to prevent contamination from the surface. Following digging/excavation the well is lined with local materials, either concrete or clay rings to prevent the walls from collapsing. Proper lining and a well-designed apron are crucial for prevention of surface water contamination.

Dugwells may provide a potable water source in some areas of Bangladesh if they are properly constructed and maintained. However, the susceptibility to bacteriological contamination is very high and this must be borne in mind at all times. It may be possible to combine dugwells with home-based surface water filters to provide a socially acceptable, bacteriologically safe water source for rural households.

6. Home-based surface water filter

There are some home-based water filters, intended for filtration of iron from tubewell water or bacteria from surface water, which are available locally in the market in Bangladesh. These are candle filters of a similar design as the Safi filter and contain porous ceramic candles. It was decided to test the effectiveness of several of these filters in removing bacteria from surface water.

The filters consist of two concrete buckets of different sizes, one of which is placed inside the other. The upper bucket is filled with water to be treated. Water then flows through a permeable 'candle' and is collected in the lower bucket where it is stored. When needed it is drawn off with a tap. A diagram of the filter is given in Figure 10. The cost of one filter is between Tk. 300 and Tk. 400.

7. *Activated alumina filter (ALCAN filter)*

MAGC Technologies Limited - a private enterprise, imported a US manufactured treatment plant. The basic principle of this system is adsorption of arsenic by activated alumina (Figure 12). In this filter the raw water passes upward through the activated alumina media. After passing through this activated alumina water becomes arsenic-free.

Figure 12: ALCAN filter

Activated alumina is formed by the thermal dehydration (250^{0}C to 1150^{0}C) of an aluminium hydroxide such as, gibbsite, bayerite, etc. Its principle characteristic is high surface area (>200 m^2/g) and associated porusness. The term activated refers to the capacity of the alumina to enter into adsorption and/or catalytic reactions, and is determined largely by such variables as crystal structure, pore size and distribution, and the chemical nature of the surface.

Technically the system is very effective. People are interested in receiving water from this unit since it is easy to use. Filtration rate is very good in the sense of serving the demand of the community only for drinking and cooking purposes.

There are two types of ALCAN systems available for use by community: household based unit and community-based unit. It has been observed that household based units are more preferred by people than that of the community-based units.

The activated alumina used as media in the system has to be imported. Initial cost is high for both type of units: Tk. 15,000 per unit (with unit + media), and Tk. 2000 (with unit + media) for the household based unit. It requires running costs because activated alumina need to be changed after every 120,000 litres of water filtered. The replacement cost of media for community-based unit is Tk. 8,000 to treat 80,000 litre of water and Tk. 1,200 to treat 11,000 litre of water.

8. Deep Tubewell (DTW)

There are two main aquifers in Bangladesh - shallow and deep. Usually there is a thick layer of silt and clay between the two aquifers. Water cannot easily pass through the layer. It has been observed

Figure 13: Deep handset tubewell

that the deeper aquifer is much less contaminated than the shallow one. A recent hydro-geological study conducted by the British Geological Survey (DPHE/BGS/MML, 1999) tested 280 tubewells the depth of which was more than 200 metres, and found unsafe levels of arsenic in only two of them – less than1%. DPHE has also tested many deep tubewells, and found only limited arsenic contamination. BRAC has also tested some deep tubewells that were contaminated with arsenic at levels that were higher than the acceptable limit. These sporadic statistics indicate the uncertain safety of the deep aquifer and careful observation is needed before making a general recommendation for this option as a safe source for arsenic free water in the future. Even so, deep tubewells cannot be drilled in all areas. This is because in some parts of the country, rocky layers make drilling impossible. Due to these constraints deep tubewells, that are not yet scientifically proven to be safe, were not included as a safe source of arsenic free water in the BRAC-UNICEF community-based arsenic mitigation project.

The availability of different alternative safe water options is very important not only to evaluate and select the best options for a particular community but also because of the physio-cultural and socio-economic variation among communities.

Members of the CNCs where tubewell water tested arsenic contaminated were asked to express their opinion about the best possible alternative water option for them. Among the options preferred by the respondents deep hand set tubewell was found to be the most popular options (42%) followed by three-pitcher filters (25%) (Table 5).

Table 6 Alternative options preferred by the members of the arsenic-affected CNCs

Preferred option	**No. of respondents**
Deep tubewell	873 (42.34)
Re-sinking of the existing wells in a deeper aquifer	258 (12.51)
Pond-sand filter	91 (4.41)
Rainwater harvester	5 (0.24)
Dugwell	112 (5.43)
3-pitcher	521 (25.27)
Iron and arsenic removal filter	117 (5.67)
Don't have any idea	85 (4.13)
Total	**2,062**

Figures within parentheses indicate percentage

Here it is mentioned that BRAC has already provided three-pitcher filters to all the arsenic contaminated CNCs operated by them.

CONCLUSION

Bangladesh is facing the problem of arsenic poisoning in drinking water. It is estimated that 95% of the population relies on groundwater for drinking purposes and nearly one- third of Bangladesh is affected by this problem (DPHE/BGS/DFID, 2000). This means that 30-40 million people are potentially at risk of arsenic poisoning in ground water. But the situation is not that grave in the CNCs because only 26% tubewell water was contaminated with arsenic more than the acceptable limit for Bangladesh. It has been observed that average daily requirement of water in more than 93% CNCs was up to 20 litres. Therefore, household-based alternative safe water device with good flow rate might be the ideal source of alternative safe water sources of the arsenic affected CNCs. Since there is no curative measure for this disease except drinking arsenic-free water (Smith 2002), alternative suitable safe water options should be made available without any delay for the exposed pregnant women and children of the arsenic contaminated CNCs of the BINP. Although majority of the villagers expressed their interest for deep hand set tubewell, yet considering the uncertainty of the deep tubewells in providing arsenic and other metal free water for the long run, other two preferred options, three pitcher and dugwells could be promoted as alternative water sources. Finally, a proper monitoring system needs to be developed to check water of contaminated tubewells as well as water of the provided alternative water options both for arsenic and bacteria on a regular basis.

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Appendix

Table 1 Depth vs. Arsenic Contamination

Depth range (ft.)	**Arsenic contamination**		**Total**
	Arsenic-free	**Arsenic contaminated**	
<50	946 (90)	107 (10)	1,053 (14)
51-150	2,097 (53)	1,827 (47)	3,924 (50)
151-250	1,061 (89)	128 (11)	1,189 (15)
>250	1,616 (100)	0	1,616 (21)
Grand Total	**5,720**	**2,062**	**7,782**

Figures within parentheses indicate percentage

Table 2 Installation year vs. arsenic contamination of the tubewells of the CNCs

Year of	**No. of tubewell**		**Total**
Installation	**As contaminated**	**As free**	**Tubewell**
1990-2001	2569	946	3,515 (45)
1980-89	2946	941	3,887 (50)
1970-79	155	108	263 (3)
1960-69	40	52	92 (1)
<1969	10	15	25 (1)
Total	5720	2062	7782

Figures within parentheses indicate percentage

Table 3 Average daily requirement of water by the CNC members

Range of daily water requirement (Liter)	Total number of CNCs
1-10	5,018 (64)
11-20	2,282 (29)
21-30	375 (5)
31-40	32 (1)
41+	75 (1)
Total	**7,782**

Figures within parentheses indicate percentage

Table 4 Detailed tubewell test results (cont'n)

Name of Upazila	Tubewell test results		Inactive/not in use	Total number of tubewells
	Arsenic contaminated	Arsenic-free		
Narshigdi Sadar	244	81		325
Barisal Sadar	189	12		201
Dumuria	168	19		187
Madaripur Sadar	84	131	1	216
Tetulia	71		3	74
Fatikchari	346		12	358
Gopalganj Sadar	30	219		249
Bhedarganj	136	41		177
Teknaf	138	8	19	165
Dacobe	81	7	63	151
Tarail	106	27	5	138
Tungipara	65	48	9	122
Monohordi	160	45		205
Damorhuda	70	15		85
Amtoli	214		8	222
Gauranadi	127	2		129
Sherpur	219	16		235
Chakaria	447	10		457
Batiaghata	109	3		112
Rupsa	83	50		133
Boda	167			167
Faridpur Sadar	133	83		216
Sadarpur	100	52		152

Annex 4 Detailed tubewell test results (cont'n)

Name of Upazila	Tubewell test results		Inactive/not in use	Total number of tubewells
	Arsenic contaminated	Arsenic-free		
Madhukhali	95	51		146
Shahrasti	5	125		130
Chandpur Sadar	57	255		312
Shibpur	165	9		174
Nikli	81	30		111
Adamdhigi	166			166
Sariakandi	179	24		203
Gabtoli	177	16		193
Sreepur	97	12		109
Mohammadpur	125	35		160
Kulaura	288	48	1	337
Rajnagar	150	32		182
Sreemongal	190	37		227
Jamalpur Sadar	304	48		352
Matlab	91	242	77	410
Banaripara	54	90		144
Bhanga	9	139	22	170
Total	**5,720**	**2062**	**220**	**8002**

BRAC-ICDDR,B Joint Project on Arsenic testing of all CNCs under BINP

Thana: District: Name of the investigator: Date:

No.	Name and code of CNC	No. of people drink TW water from CNC (daily)		Average daily requirement of water (litre) of the CNC	Water sources of the CNC members at home	Arsenic test result of the CNC TW	Painted color (red/green)	Depth of the TW	Yr of Installation	If arsenic contaminated, what would be the alternative best option
		Women	Children							
1										
2										
3										
4										
5										
6										
7										
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