Arsenic Mitigation in Bangladesh

An outcome of the International Workshop on Arsenic Mitigation in Bangladesh, Dhaka 14-16 January, 2002, organized by The Local Government Division, Ministry of Local Government Rural Development & Cooperatives, Government of the People's Republic of Bangladesh

Edited by:

M. Feroze Ahmed Ph.D.
Professor of Civil/Environmental Engineering,
BUET, Dhaka-1000, Bangladesh

Chowdhury Mufad Ahmed
Senior Assistant Secretary
Local Government Division
Ministry of LG,RD and Co-operatives
Govt. of the people's Republic of Bangladesh

October, 2002

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Published by:

The Local Government Division,
Ministry of Local Government Rural Development & Cooperatives Government of the People's Republic of Bangladesh.

With Assistance from:

ITN-Bangladesh
Centre for Water supply and Waste Management
BUET

October, 2002

ISBN 984-32-0349-6

Print and design by:
Progressive Printers Pvt. Ltd.

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1 RECOMMENDATIONS OF THE WORKSHOP

1.1 HYDROGEOLOGY GROUP

1.1.1 Screening of Tubewells

- Government has given due priority of screening of all tube wells. It is recommended that the process be accelerated and screening of all the tube wells both hand pumps and irrigation wells (approx. 10 million) be completed by field kits on Priority Basis in highly contaminated areas in accordance with the guidelines of the Government's Policy for Safe Water Supply and Sanitation, 1998 (short term).

- Reliable testing facilities should be available to people at a reasonable cost. (short term).

- Quality control of field surveys is essential for which Reference Laboratories to validate field test results be established on a priority basis (short term).

1.1.2 Monitoring of Screened Tubewells

System be developed to monitor the presently found safe wells, if possible once a year (mid term goal).

1.1.3 Aquifer Mapping

- Immediate mapping be based on existing data of tubewells on Arsenic concentration and depth of wells if location is available. This should be used as local level guide for new tubewells (short term).

- Priority Project should be undertaken to find criteria for mapping the Upper, Middle and Lower aquifers (Holocene and Plio-Pleistocene sediments) on Upazila as units. Union level exercise may be tried at a later date (mid term).

- Because arsenic is related to geology, a priority project should be undertaken for mapping of facies, geometry and chemistry, and classification of the Holocene sediments and correlate them to the aquifer systems.

1.1.4 Groundwater Management

- In those areas where groundwater is known to be safe, it should continue to play a role in providing safe water supplies. But this must be supported by a monitoring program (short term).

- In arsenic affected areas, no new irrigation wells should be installed in the arsenic safe aquifer to protect the presently safe water supplies. This aquifer is frequently found at greater depth. (short term).

- The abstraction rate of the safe aquifers needs to be determined to assess the potential for sustainable future water supplies from this resource (short term).

- Ensure that the entire population has access to arsenic safe water (mid term).

- Determine uses that require arsenic safe water such as cooking, drinking and agricultural, etc (short term).

- Monitor the quality and quantity of groundwater for those purposes requiring safe water particularly for arsenic (mid term).

- Develop enforceable standards for water well construction to prevent cross-contamination of aquifers (short term).

1.1.5 Research

- Investigate the source, release mechanism and mobilization of arsenic in the ground water on a priority basis (short term).

- Detailed analyses and transport properties of the aquifer sediments should be undertaken (mid term).

- Research on soil build-up of arsenic through arsenic laden irrigation water and bio-availability of arsenic and its subsequent entry into crop, agriculture and food chain (mid term).

- Evaluate methods of in-situ arsenic removal from groundwater as an alternative method for supplying arsenic safe water (mid term).

- Evaluate the effects on hydrologic and geochemical systems to actual and future development of the groundwater resource (short term).

- Identify isotopic signature of arsenic contaminated water from arsenic safe deeper aquifers and to study the interactions between shallow and deeper aquifers (mid term).

- Investigate the seasonal changes in arsenic concentration and other information required to develop a reliable and cost effective monitoring program (short term).

- Develop simple tools to assist local drillers in site and depth selection (mid term).

1.1.6 Administrative and Legal Issues

- Groundwater is a valuable natural resource. A suitable "Groundwater Act" should be enacted to control all activities regarding sustainable groundwater exploration, development and management (short term).

- A national standard should be established for arsenic content of irrigation by groundwater (short term).

- There is no single organization in the country that deals with all aspects of groundwater although all our neighboring countries have organizations such as "Groundwater Commission", "Groundwater Board" or "Groundwater Agency". The Government should create or identify an organization bringing all the personnel working on groundwater under one umbrella organization.

- Government should coordinate all stakeholder activities in the sector based upon their approved strategy.
- Local Government Institutions should be given sufficient resources in recognition of its key role in ensuring provision of arsenic safe water to the people.
- An international center for groundwater related research and training needs to be established in the country.

1.3 ALTERNATIVE WATER SUPPLY GROUP

1.3.1 General Observations

The alternative water supply group recognized that:

- alternative technologies are area dependent and cannot be generalized for the whole country;
- the country is broadly divided in Shallow Water Table Area, Low Water Table Area, Coastal Saline Area, Stony Area and Chittagong Hill Tracts Area requiring technological variations;
- no single option can serve the needs of the people having different social and economic conditions;
- choices of the communities should be given priority in the selection of technological options;
- the areas with high density of contaminated tubewells also have high levels of arsenic in tubewell water, which have multiplying adverse health effects on consumers;
- there exists knowledge gap in some areas that impedes decision making regarding selection of alternative technologies for arsenic affected areas.

1.3.2 Alternative Water Supply Options

Recommendations

The following alternative water supply options are recommended for arsenic mitigation in Bangladesh:

Emergency Option

- In acute arsenic problem areas (where more than 80% tubewells are contaminated) an alternative safe water point appropriate in the

area is to be provided in each village on an urgent basis following ongoing national screening program.

Short-term Options

A water supply option for an area is dependent on availability, quality and development potentials of alternative water sources in the area. The possible technological options (not in order of priority) are given below:

- Deep tubewell (where suitable aquifers are available).
- Dug/Ring well (where technically feasible).
- Rainwater harvesting.
- Treatment of surface water (where surface waters of good quality and of adequate quantity are available).
- Treatment of arsenic contaminated water.

Short-term options are to be provided under arsenic mitigation program in areas where more than 40% tubewells are contaminated. The people living in areas where less than 40% tubewell contaminated are expected to get uncontaminated tubewells within reasonable distances for collection of drinking water.

Long-term Options

- Proven safe and sustainable technologies implemented under short-term options.
- Piped water supply.

1.3.3 Area Specific Selection of Options

Recommendations

The possible areas for different alternative water supply technologies are recommended below based on limited available information. The requirements for adoption of the technologies are also given.

Deep Tube Wells

Manually operated deep tubewells are source of safe and reliable water supply in many parts of the coastal area. In other areas, safe deep aquifers may be available to produce water of acceptable quality for water supply.

Requirements

- It is important to first delineate the areas where such deep aquifers are available that are separated from shallow contaminated aquifers by relatively impermeable layers.
- The annular space of bore holes of the deep tubewells are required to be sealed at the level of impermeable strata to avoid percolation of arsenic contaminated water.

Dug/Ring Wells

Dug wells may be constructed where feasible for arsenic safe water supplies. The areas with aquifers at shallower depth and the hilly areas are suitable for construction of dug wells. The areas with thick consolidated clay layers are not suitable for dug well construction. Construction difficulties may arise in loose sandy/silty soils.

Requirements

- Sanitary protection and provision for disinfection of dug well.
- Dug/ring wells are required to be tested in an acute arsenic problem areas for arsenic content under following conditions of :
  - continuous withdrawal of water for few days; and
  - complete sanitary protection.
- Study on the possibility of contamination from on-site sanitation.

Rainwater Harvesting

Rainwater harvesting has good potential for water supply in all arsenic and salinity affected areas in Bangladesh. In the absence of easily available alternative sources of water supply, this option is more suitable in the coastal islands, southwestern part of coastal area and hilly regions of Bangladesh.

Requirements

- Motivation of the people to practice rainwater harvesting.
- Standardization of catchment area and storage tank in relation to rainfall intensity and distribution in Bangladesh.
- Monitoring of water quality, particularly during the lean period.

Surface Water Treatment

Treatment of surface water can be an option in any part of Bangladesh having perennial surface water of adequate quantity and of good quality. The flowing rivers, large reservoirs, oxbow lakes and protected ponds are preferred surface water sources. The technologies include:

- Slow Sand Filters (SSFs)/ Pond Sand Filters (PSFs)
- Pressure/Rapid filtration followed by disinfection.
- Small-scale conventional or prototype treatment plants
- Conventional surface water treatment plants

Requirements

- Removal of impurities of any health concern to acceptable levels.
- Desired level of clarification and disinfection.

Treatment of Arsenic Contaminated Water

Some units developed for treatment of arsenic contaminated water at household and community levels and installed for experimental use in different parts of Bangladesh have shown very good potentials for use in water supply in all arsenic affected areas. Centralized arsenic removal plant has been proved feasible in few urban centres having arsenic contaminated production wells. In period of scarcity, arsenic treated water may supplement other sources of arsenic-safe water.

Requirements

- Protocols for management of sludge and wastewater rich in arsenic are needed to be developed.
- Validation of technologies is essential prior to large-scale implementation.

Piped Water Supply

Piped water supply is the long-term goal of water supply in Bangladesh and should be introduced in phases.

- In an urban center with piped water supply, the people dependent on shallow tubewells in the periphery can shortly be brought under piped water supply through expansion of existing areas of service coverage.
- Piped water supply should also be introduced in the small urban centers fully dependent on contaminated shallow tubewells.
- Piped water supplies are also possible for clustered households in villages, growth centers and the rural areas having good rural road network.

Arsenic-safe water for piped water supplies may be available from any sources such as deep tubewell, treated surface or arsenic contaminated water or water from community dug wells.

1.3.4 Monitoring and Surveillance

Recommendations

Performance and quality of water of the existing safe tubewells and the proposed short-term options need regular monitoring and surveillance.

1.3.5 Institutional Arrangement for Implementation of Alternative Water Supply

Vision Statement

Safe and adequate amount of water will be provided for drinking and cooking in all households through effective, efficient and sustainable institutional arrangement. Services will be provided and managed locally, which will be transparent and accountable to the people. National interests and public goods issues will be addressed by the Central Government.
(Safe: arsenic-safe and free from other chemical and microbial pollutants)

Recommendations

The roles and responsibilities of various actors in safe water supply and capacity building for arsenic mitigation in Bangladesh are outlined below:

Role of Central Government

- A national legislation for water quality and supply for regulation, monitoring and implementation should be developed. National Water Council must play an important role in this process.

- The regulatory capacity of DPHE to provide technical guidance and monitoring for supply of safe water should be strengthened.

Role of Local Government

- The governmental policy of decentralized provision of services related to safe water options through the Union Parishads (UP) should be operationalized immediately. This will lead to a much

closer involvement of local government in the implementation of safe water options.

- UPs should also be involved in mobilizing resources, monitoring and information management; more specifically registration of tube wells can be undertaken by the UPs.

Role of Communities and NGOs

- Local communities must be facilitated and empowered to undertake planning, implementation and management of safe water options. This should be based on informed choices. NGOs must play a vital role in this process.

- There should be a strong focus on capacity development at the local and/or community level for technical implementation and monitoring. Formation of user groups for local implementation and monitoring should be encouraged throughout the country with support from NGO's and the local government.

Role of Private Sector

- The private sector can play a key role in implementation of safe water options and interacting with the end users. This role should be included in the mainstream national policy for provision of safe water options and development of innovative, enterprising solutions should be encouraged.

- Involvement of private sector in financing of well monitoring and safe water options should be encouraged through tax relief and other incentives.

Capacity Development

- Institutional capacity development for the regulatory functions and monitoring should be undertaken by the Central Government (Ministry of LGRD and Cooperatives).

- Capacity development at the local and community level should include technical capacity for installation, operation &

maintenance, and monitoring should be a key element of the national policy. This should also include the capacity for information management and reporting.

Information Management and Applied Research

- Knowledge and information should be managed centrally to ensure transparency of the implementation process. Ready accessibility of information to all stakeholders is essential. Governmental institutions, such as NAMIC, should undertake this sustained role of functioning as an information warehouse at the national level.

- Centers of excellence on relevant research on safe water options should be developed. These centers should focus on existing information and knowledge leading to identifying and conducting research on key areas.

1.3.6 Task Force

Recommendations

A Task Force led by DPHE may be constituted to undertake prioritizations of safe water options and develop strategies for their implementation.

- The Task Force should focus on:
  - a clear time frame for implementation;
  - the formulation of a protocol that includes technological and socio-economic criteria; and
  - a strategy for information management and dissemination.

- The Task Force will formulate the roles and responsibilities of the ministries, departments and directorates, local government institutions, research institutions, private organizations, NGOs and CBOs.

The information emerging from the Task Force should be adequate for making informed choices by communities.

1.3.7 Research and Development

Recommendations

In quest of addressing the issue of knowledge gaps, research and development initiatives are needed to be undertaken in diverse fields of alternative water supply in Bangladesh. Some of them are listed below:

- Leaching characteristics of arsenic rich sludges under different conditions and possible contamination from arsenic rich effluents produced by arsenic removal technologies.
- Development of protocols for safe disposal of sludge and wastewater rich in arsenic
- Development of construction, operation and maintenance manuals for each of the following:
  - Rainwater harvesting
  - Deep Tubewell
  - Dug wells
  - Pond Sand Filter
  - Small-scale water treatment plant
  - Piped water supply
- Effect of sanitary protections and continuous withdrawal of water on arsenic content of dug well water.
- Study on the possibility of contamination of dug well water from on-site sanitation (pit latrines).
- Development of a combined roughing and slow sand filtration unit suitable for surface water treatment in Bangladesh.
- Development of an accurate and reliable field kit for measurement of arsenic at the village level.
- Development of effective, affordable and environment friendly arsenic removal technologies for use in rural areas of Bangladesh.

- Mechanism of recharge of deep aquifers and possibility of contamination of deep tubewells in arsenic affected areas.

- Analysis of water supply situation including population exposed to arsenic contamination based on updated data available from on-going studies and national screening program.

- An evaluation of effectiveness, impact and replicability of arsenic mitigation initiatives in Bangladesh.

- Study of existing water treatment plants in operation in Bangladesh; identification of problems and possible solutions for application in the design of appropriate water treatment technology.

Part 2

Theme Paper – I

Hydrogeology and Arsenic Contamination in Bangladesh

Prepared by:

M. Nazrul Islam
Director General

and

Md. Nehal Uddin
Deputy Director
Geological Survey of Bangladesh
Government of the People's Republic of Bangladesh

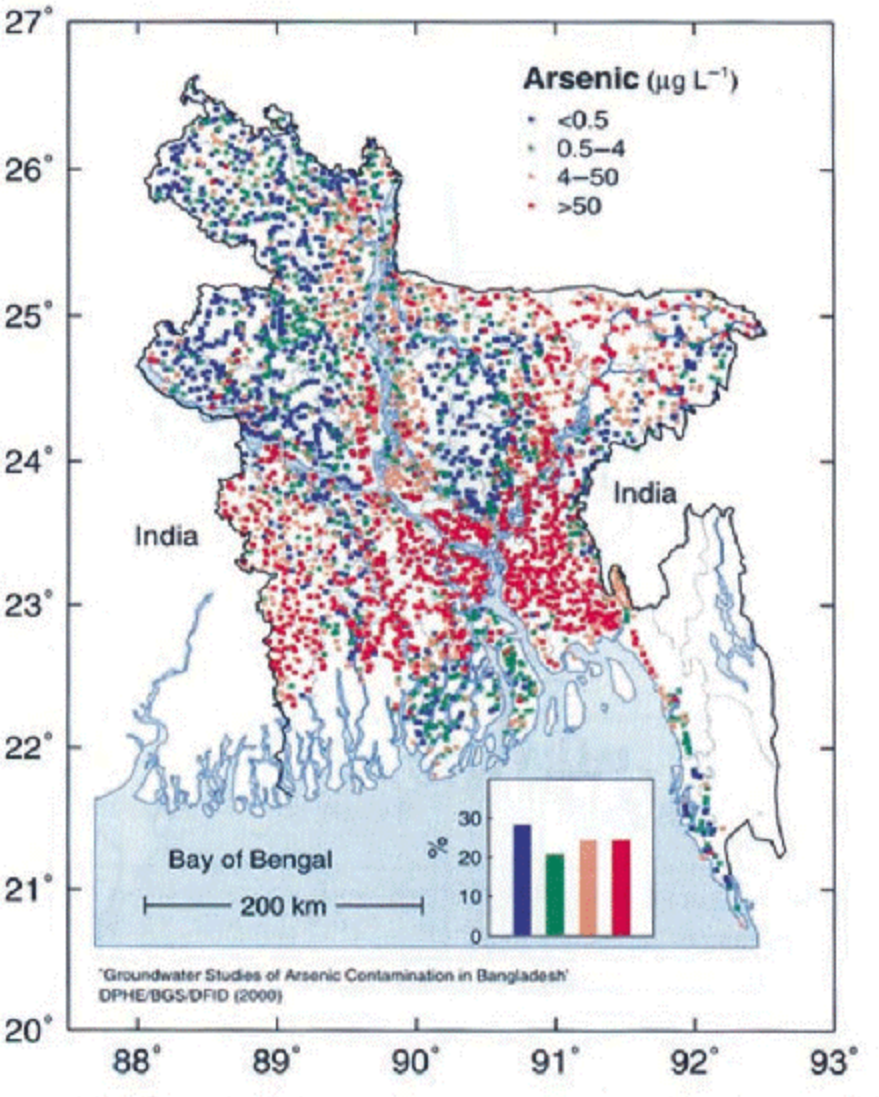
2 HYDROGEOLOGY AND ARSENIC CONTAMINATION IN BANGLADESH

2.1 INTRODUCTION

After independence, the Government of Bangladesh undertook, a massive program to provide bacteriologically safe drinking water for the people of the country. As a result millions of shallow tube wells (hand pumps) were installed to extract safe drinking water. Exact numbers of the tube wells are not known but the number may be from 8 to12 millions. Simultaneously, for self-sufficiency in food, the cultivation of high yielding variety of rice spread all over the country and large number of deep and shallow tube wells for irrigation were sunk.

The latest information shows that in 61 out of 64 districts, tube wells in various percentages are producing water with arsenic higher than the national standard of 0.05 milligram per liter (Figure 2.1). In many Upazilas (sub-districts) more than 90% of the tube wells are producing water that are not safe for drinking or cooking purposes. The problem of arsenic contamination of the ground water became known from 1993 but unfortunately it did not get the proper attention till very recently. By this time more than 30 million people are already facing the problem and probably 70-80 million people are threatened with the problem. This shows the enormous magnitude of the problem faced by the country. Some other countries like India (West Bengal part of the Bengal delta), China, Vietnam and Laos are also facing similar problem (Figure 2.2).

By this time we have enough evidence that the wells with higher than permissible level of arsenic have a direct relationship with the location and geological age of the aquifers. We feel that the time has come to make the proper map of the aquifers, find their geological age and relate them with the geological evolution of the Ganges-Brahmaputra-Meghna Delta Complex.


Arsenic (µg L⁻¹)
<0.5
0.5–4
4–50
>50
India
India
Bay of Bengal
200 km
%
30
20
10
0
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

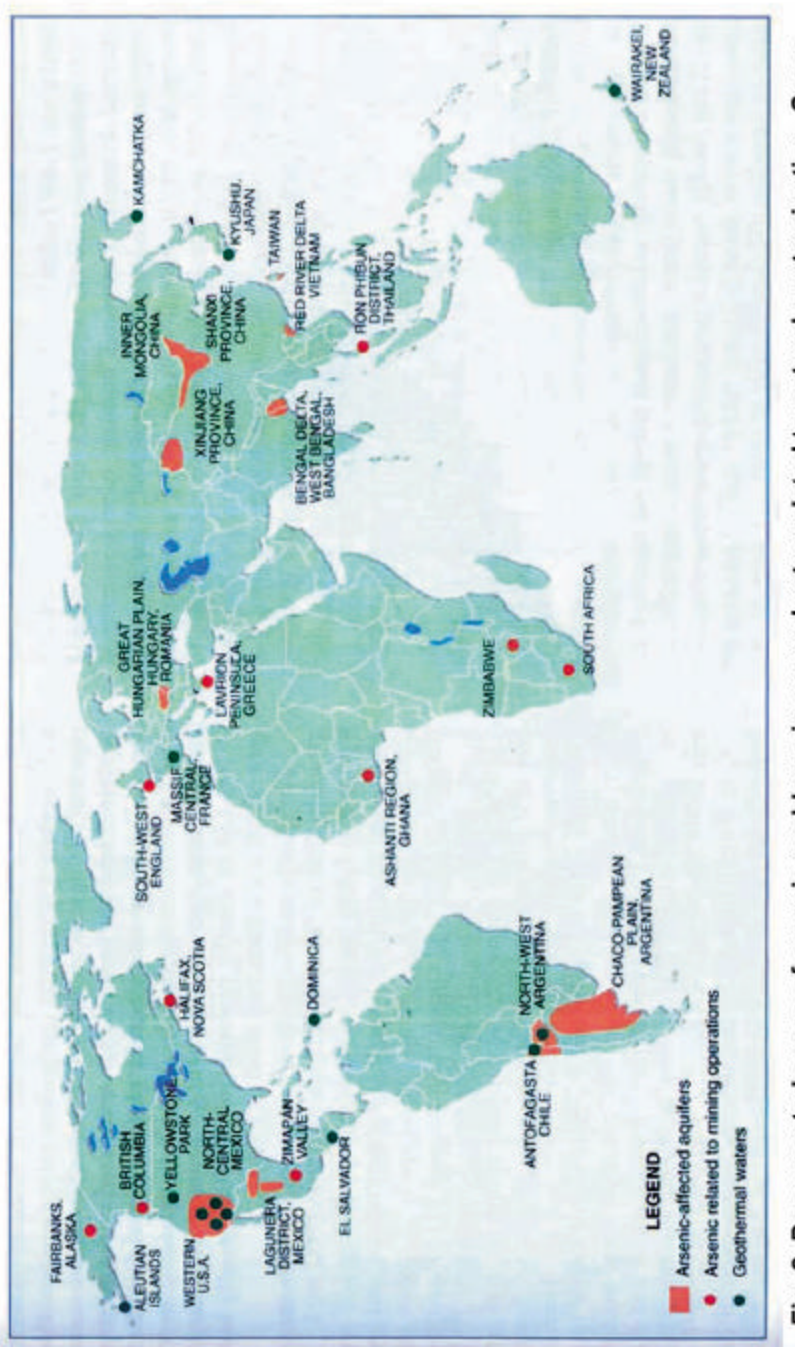


Fig. 2. Documented cases of arsenic problems in groundwater related to natural contamination. Cases inlude some of major mining and geothermal occurrences reported in the literature (Source DFID 2001)

4.4. ARSENIC MITIGATION INITIATIVES BY DIFFERENT ORGANIZATIONS IN BANGLADESH

4.4.1. Department of Public Health Engineering (DPHE)

Although in 1993 the presence of arsenic in tubewell water was first detected, the magnitude and extent of the problem was not known clearly before 1997. Various agencies and DPHE conducted tests of tubewell water samples from different districts randomly and a comprehensive test could not be done due to lack of testing facilities in Bangladesh. DPHE with the donor agencies is conducting various survey, study and mitigation activities in the country. A brief on arsenic related projects is as follows;

Under the assistance of UNICEF the testing of arsenic in water sample of tubewell water with field kit was started from July 1997 all over the country. Over 50 thousand tests were conducted and in 190 Upazilas presence of arsenic contamination was found. The survey indicated a contamination of 27% tubewell among the tested wells. Under the project 170 exploratory drillings were done in arsenic problem areas, where 95% of the tubewell having depth> 200m shows no arsenic contamination. Awareness building activities were also done under this project. The cost of the project was Tk 199.59 lakh with PA Tk 134.00 lakh. The project started on October 1996 and ended on June 2000.

DPHE-UNICEF action research project in 5 Upazilas : A project was implemented in 5 Upazilas of the affected areas. These are Manikganj, Sonargaon, Kochua, Bera and Jhekargacha. The activities were conducted by engaging 4 NGOs. The four major activities were conducted in these upazilas. Those are awareness building, testing of tubewell water sample and marking with paint the contaminated and uncontaminated tubewell. Identification of patient suffering from arsenicosis and providing alternative water supply options particularly the demonstration of them. A total of 105179 tubewells have been tested and an average contamination of 60% was found. Under the project about 1.2 million people have been surveyed for arsenicosis and a total of 744 patients were identified. The

project also provided 13,733 safe water options (28 deep tubewell, 13 tubewell sand filter, 13 dug wells, 266 rainwater harvesting tank, 52 PSF, 4 community type plant and 13357 – Kolshi filter) to the community for action research. The project was implemented as R&D activities and a follow up action program is continuing. Under the follow up programme, apart from the usual mitigation options, Mini piped water supply system is under implementation at Sonargaon Upazila. On the other hand, community based arsenic removal plants have been installed and under installation at Bera Upazila.

DPHE-UNICEF has started a similar program in 15 Upazilas under arsenic affected areas and an investment project for arsenic mitigation in 25 Upazilas will be taken up in the year 2002. A total of 7.5 US $ will be provided by UNICEF for this project. Under this project by November 2001 a total of 221174-tubewell water samples have been tested out of which 70% were found contaminated.

Under the assistance of British DFID, DPHE and British Geological survey conducted a systematic and comprehensive survey in 61 districts (except in 3 hilly districts). About 3500 water samples were collected from field and tested in DPHE laboratories in Bangladesh and BGS laboratory in England. The survey indicated that in 249 Upazilas of 61 districts the problem exists. But the magnitude of the problem is not same in everywhere. The variation of affected tubewell in Upazila varies from 1% to over 90%. The most affected areas lies in south south-eastern part of Bangladesh. In country context about 28% of the tested samples show arsenic concentration above the Bangladesh limit of 50 ppb. The study indicated the deep aquifer in the coastal belt is nearly safe to contamination (0.7% contaminated). The cost of the project was Tk 609.29 lakh with PA Tk 578.35 lakh. The project started on December 1997 and ended on March 2000. The combined survey of DPHE-UNICEF-DFID identified 268 Upazila having arsenic problem in 61 districts(excepting 3 hill tracts districts)

DPHE under the assistance of JICA is conducting a study to investigate the deep groundwater and possibility to use it for the mitigation of arsenic problem in three western districts of Bangladesh (Jessore, Jhenaidah & Chuadanga). The study started on May 2000 and will continue up to

March 2002. The out come of the project is yet to be finalized. The cost of the project is estimated of Tk 2599.04 lakh with PA of Tk 2460.61 lakh.

DPHE-DANIDA Arsenic Mitigation Pilot Project: A pilot project under DPHE-DANIDA has been taken up in the south-eastern part of Bangladesh. The estimated cost of the project is about Tk 7070.57 lakh . The project is designed for three years and a half (upto June'2004) and will be implemented in two phases. The main components of the project will be Deep tube well, Mini piped water scheme, Household treatment unit. The project has started its activities in the project areas under DANIDA.

DPHE, under GOB-4 project is implementing several alternative water supply options like PSF, Ring well and Deep TW in arsenic affected Upazilas. No shallow tubewells are installed in these affected areas.

DPHE under R&D activities conducted the following activities;

- Hydrogeological investigation at Chapai Nawabganj area with the Department of Geology, Dhaka University.
- Surface sounding at Bera Upazila to locate arsenic uncontaminated aquifers.
- Pathway investigation of arsenic contamination in production wells with the Department of Geology, Dhaka University.
- Use of activated alumina for development of household arsenic removal unit with BUET.
- Development of multimedia communication messages of arsenic, which are being used in awareness building activities.
- Random testing of 5 tubewell water samples in each village of arsenic safe 199 Upazilas to confirm the contamination level (Planned for 2002).

UNICEF finances all the above R&D activities.

Alternative Technology Options

Rainwater harvesting, pond sand filter, ring well, deep tubewell,
household arsenic removal units, community based arsenic removal units,
village piped water supply, urban arsenic treatment plan.

4.4.2 Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP)

Brief Description

Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) was conceptualized jointly by the Government of Bangladesh, the World Bank and the Swiss Agency for Development and Cooperation. The project was launched in September 1998. The overall objective of the project is to reduce mortality and morbidity in rural and urban population caused by arsenic contamination of groundwater within sustainable management strategies. Project activities include understanding of the arsenic problem through national survey; strengthening implementation capacity of the local government entities and community based organizations; and onsite mitigation through subproject development and implementation by the community based organizations.

Arsenic Mitigation Experience

BAMWSP initiated a nationwide screening, community development and mitigation program. Screening of tubewells are being conducted in 147 Upazillas and 100 municipalities. Mitigation activities are going on in 35 Upazillas. Major planned activities include strengthening the capacities of local government institutions, establishing rural safe water supply management and providing necessary support to the communalities for building up their capacities in water supply management.

The project has under taken a program to cover 188 Upazillas for screening, community development and mitigation. Through this project, screening, community development and mitigation in 6 Upazillas have been completed. Screening of another 35 Upazillas have been completed, and community development and mitigation program of this component will be completed by June 2002. The screening, community development and emergency mitigation of another 147 Upazillas will be completed by June 2003

Alternative Technology Options

Pond sand filter, dug well, deep tubewell.

4.4.3 UNICEF

Brief Description

The UNICEF Program of Co-operation with the Government of Bangladesh contributes to the realization of women's and children's rights through a variety of inter-sectoral and sectoral initiatives in health, education, water, sanitation, protection, and early childhood development. The Water and Environmental Sanitation (WES) Program of UNICEF improves access to safe water and sanitation, especially in un- and under-served areas, works with government and its partners to mitigate the arsenic crisis and is also promoting a sanitation and hygienic package for school children.

Arsenic Mitigation Experience

The WES program has adopted an integrated sanitation, hygiene and water supply demand-driven approach in partnership with other development partners. The program includes support for testing water quality and exploring alternate low-cost safe water technologies. Arsenic mitigation activities of the program includes improving water quality (including arsenic measurement, mitigation and research) to urgently address the problem of arsenic contamination, and the blanket testing of 1,000,000 tube wells in 45 Thanas (1/4 of the area affected), information and awareness campaigns, equipping zonal laboratories for water quality testing, training staff and providing alternative water technologies to affected communities. The program continues to work closely with the World Bank-supported Bangladesh Arsenic Mitigation and Water Supply (BAMWSP) project and with other international agencies and NGOs.

Alternative Technology Options

Rainwater harvesting, pond sand filter, ring well, dug well, tubewell sand filter, deep tubewell, household and community based arsenic removal units, iron-arsenic removal unit, surface water treatment unit, piped water supply

4.4.4 Bangladesh University of Engineering and Technology (BUET)

Brief Description

Bangladesh University of Engineering and Technology (BUET) is the highest seat of technical education and research in Bangladesh. BUET is conducting research in the field of arsenic contamination in collaboration of few leading institutions of the world. The research interests in the filed of arsenic mitigation include arsenic removal from groundwater, surface water treatment and rainwater harvesting.

Arsenic Mitigation Experience

Bangladesh University of Engineering and Technology is conducting research in arsenic mitigation and some of the BUET technologies are under extensive field test in different parts of the country. BUET activated alumina unit has been tested in different regions of the country under rapid assessment of arsenic removal technologies conducted in Bangladesh and found very efficient in arsenic removal as a household arsenic removal technology (BAMWSP, DIFID and Water Aid, 2001). The unit has been modified based on the input from social studies conducted under the same assessment. The BUET modified bucket unit based on ferric chloride and potassium permanganate is working successfully for two years in Barura Thana in Comilla districts. The modified BTU has been found very effective in removing arsenic, iron, manganese, phosphate and silica. BUET has manufacture iron-coated sand for arsenic removal and experimental units based on iron-coated sand have been installed in rural areas. The arsenic-cum-iron removal unit designed by BUET is working in different parts of the country. BUET has installed few experimental pond sand filters in the rural area with some modification in the existing design. BUET is also providing services to entrepreneurs in testing of arsenic removal technologies in laboratory and field conditions.

Alternative Technology Options

Household based arsenic removal units, arsenic-iron removal unit, and pond sand filter.

4.4.5 NGO Forum for Drinking Water Supply and Sanitation

Brief Description

NGO Forum is a national apex networking and service delivery organization in the water supply and sanitation sector dedicated to contribute in the improvement of the public health status of the poor and disadvantaged women, children and men of Bangladesh. NGO Forum comprises of over 600 partner NGOs, CBOs and private sector actors who implement water supply and sanitation program at the un-served and under-served rural and urban communities. This organization is committed to contribute to reducing morbidity and mortality caused by water and excreta-borne diseases ensuring safe, accessible affordable and sustainable water supply and sanitation services adopting software-hardware mixed approach. The Forum promotes adaptive learning and community-managed water supply and sanitation services. It utilizes its vast experience and works as development partner with all concerned NGOs, CBOs and private sector, national and international agencies and other stakeholders to promote sustainable safe water supply and sanitation facilities.

Arsenic Mitigation Experience

NGO Forum has so far under taken seven projects and programs on arsenic mitigation. These activities range from installing alternative arsenic safe water sources to establishing an information support unit for NGOs. It is providing training for trainers in 147 Upazilas and 100 municipalities. NGOF has introduced a number of mitigation options including pond sand filters, arsenic removal plants, rainwater harvesters, dug wells, and piped water system.

Alternative Technology Options

Rainwater harvesting, pond sand filter, arsenic-iron removal plant, dug well, piped water supply

4.4.6 BRAC

Brief Description

BRAC, a national private development organization, was set up in 1972. BRAC was initially established as a relief organization to afford relief and assistance to resettle refugees returning from India after Bangladesh's liberation war. The task of relief and rehabilitation over, BRAC turned its focus on the long-term issue of poverty alleviation and empowerment of the poor in the rural areas of Bangladesh. Today, BRAC promotes income generation for the poor, mostly landless rural people of Bangladesh, through micro-credit, health, education and training programs. Previously known as Bangladesh Rural Advancement Committee, BRAC is now a multifaceted organization with over 25,000 regular staff and 31,000 part-time teachers, working in 50,000 villages in all the 64 districts of Bangladesh. The projected budget of BRAC in 2001 is US$ 153 million of which Donor contribution accounts for 21%.

Arsenic Mitigation Experience

BRAC, in collaboration with DPHE and UNICEF, has been conducting an action research program on community-based arsenic mitigation in two Upazilas (Jhikorgacha and Sonargaon) since June 1999. The objectives of this project are to assess the technical viability and effectiveness of various alternative safe water options as well as their social acceptance. BRAC also screens tubewells for arsenic contamination, builds awareness among communities, identifies arsenic patients and provides medical care. BRAC has recently started to implement low-cost piped water supply schemes in several villages in collaboration with the Rural Development Academy and local communities. Under these schemes local communities contribute 20% of capital costs and 100% operations and maintenance costs of the projects.

Alternative Technology Options

Rainwater harvesting, pond sand filter, dug well, deep tubewell, household arsenic removal units, community based arsenic removal units, village piped water supply.

4.4.7 Dhaka Community Hospital (DCH)

Brief Description

Dhaka Community Hospital is a trust owned, non-profit making, self-sustaining healthcare organization. It was established in 1988. Since its inception, DCH has been experimenting an integrated and sustainable healthcare delivery system at affordable cost both in urban and rural areas of Bangladesh. It has successfully introduced health insurance scheme in its project areas bringing modern healthcare facilities to the less affluent section of the population.

Arsenic Mitigation Experience

DCH is the pioneer organization in the field of arsenic mitigation in Bangladesh. DCH was one of the first institutions to detect arsenic patients in the country. Since then DCH has conducted arsenic detection and patient identification programs in many parts of Bangladesh. DCH also manages arsenic patients and build public awareness through its various programs.

Alternative Technology Options

Rainwater harvesting, pond sand filter, dug well, household arsenic removal units.

4.4.8 Asia Arsenic Network (AAN)

Brief Description

The Asia Arsenic Network (AAN) is a Japanese citizens' association established in April 1994 based on the experience of helping arsenic victims in Japan. In Bangladesh, AAN has been working since 1996 to find out the measures to obtain alternative sources of safe drinking water and to reduce the sufferings of arsenic victims.

Arsenic Mitigation Experience

The Asia Arsenic Network carried out a comprehensive project in Samta village of Jessore district. The project had been carried out for three years from March 1997 to February 2000 under promotion of the Toyota Foundation. Its purpose was to investigate the actual conditions and cause

behind the arsenic contamination of groundwater, and take measures in coordination with local researches and residents. In April 2000, AAN started its "Mobile Arsenic Center (MAC)" activities. MAC is a comprehensive approach by a team of professionals in the medical, chemical, water supply engineering and awareness education fields. At the present moment, AAN conducted MAC programs in thirteen villages of Jessore, Jhenidah, Satkhira, Meherpur and Chuadanga.

Alternative Technology Options

Rainwater harvesting, pond sand filters, dug well, deep tubewell.

4.4.9 Grameen Bank

Brief Description

Grameen Bank, a specialized financial institution providing group-based credit to the landless and assetless poor started its operation in 1976. Grameen Bank has nearly 2.4 million members of whom 95% are women. It is serving through 1,152 branch offices covering about 60% of the villages in the country. Currently it disburses 30-40 million US Dollars a month through a variety of loans. The Grameen Bank loans are completely free of collateral. The main objective of the bank is to make banking services available to the landless rural poor and bring positive changes in their lives and socio-economic condition.

Arsenic Mitigation Experience

In October 1997, Grameen Bank has started an arsenic mitigation pilot project with assistance of UNICEF and Department of Public Health Engineering (DPHE). The program was implemented in Kochua upazilla of Chandpur district. The first phase of the project was started in 20th August 1999 in three unions. In December 1999, the project area was extended into 12 unions. The main objective of the project includes screening of tubewells, awareness and capacity building of the community, and community-based solutions for arsenic contaminated areas.

Alternative Technology Options

Rainwater harvesting, pond sand filter, household arsenic removal units.

4.4.10 PROSHIKA

Brief Description

PROSHIKA Manobik Unnayan Kendra is a national NGO primarily involved for human development in the country. For almost three years PROSHIKA has been involved in supplying safe water in arsenic affected areas through treatment of surface and arsenic contaminated waters. PROSHIKA has installed a large number of community and household based water treatment units in Bangladesh.

Alternative Technology Options

PROSHIKA has undertaken a project in collaboration with Canada Water Purifier Limited to manufacture as well as widely distribute a filter called "Bishuddha" in Bangladesh. Since inception in November 2000 more than 20,000 filters have been manufactured and more than 15,000 filters have been sold to NGOs, Government and others.

PROSHIKA has been pioneered the production of a kind of surface water treatment plant called 'Nirapad' in collaboration with a Belgium farm,'Altech'. The first plant was experimentally set up in Tungipara Upazila under Gopalganj district. Later, 1 in Monla, 2 in Manikgonj, 1 in Gopalgonj, 1 in Mathbaria, 1 in Rampal and 1 in Pirojpur have been installed. It has a production capacity of around 1200 litters per hour and can supply drinking water to 2000 consumers in arsenic affected areas.

PROSHIKA has installed continuous groundwater arsenic removal plants based on *AdsorpAs*® (Granular - ferric Hydroxide), a technology developed by M/s Harbauer GmbH, Germany in co-operation with Technical University of Berlin. *AdsorpAs*® based units have been set up by PROSHIKA in different areas – 2 in Chapainababganj, 1 in Bhanga, 2 in Mirsharai, 3 in Faridganj, 1 in Raipur and 2 in Horirampur. PROSHIKA has also installed similar sorptive media based arsenic removal plants developed by ADHIACON, Environment Protection Engineers, India in Saturia, Ghior, Manikgonj Sadar, under Manikgonj District. These arsenic removal plants are running with full satisfaction of the local people.

4.4.11 Aqua Consultants Aand Associates Ltd.

AQUA Consultants and Associates Ltd. is a private consulting firm providing services to the WSS sector. AQUA under the assignment from DPHE designed and implemented a number of urban water supply programs where arsenic removal plants were constructed. Most of these constructions were carried out in the later part of 1990s and completed in 2001. Plants are located in six different district towns and were originally designed as iron removal plants. Since iron removal plants also work as arsenic removal plant and arsenic was found to be present in groundwater in those urban towns, the units were then termed as iron-arsenic removal plants. The plants provided arsenic safe water to 6 urban centers where both arsenic and iron are present in groundwater. The plants are relatively expensive and there is no provision for safe disposal of sludge.

4.4.12 Bangladesh Engineering and Technological Services Limited (BETS)

Bangladesh Engineering and Technological Services Limited (BETS) is a private consulting firm providing services to the WSS sector. BETS was associated with the 'Rapid Assessment of Household Level Arsenic Mitigation Techniques' as local counterpart to WS Atkins International Limited during September 2000 to March 2001. Currently BETS is conducting a study on "Groundwater Development of Deep Aquifers for Safe Drinking Water Supply to Arsenic Affected Areas in Western Bangladesh" started in June 2000.

4.4.13 Other Organizations

There are many other organizations involved in arsenic mitigation in Bangladesh. Information about their works in arsenic mitigation could not be collected within the short period of preparation of this report.

4.5. INSTITUTIONAL ARRANGEMENT FOR SERVICE DELIVERY

4.5.1 PAST EXPERIENCE

During late sixties, District Councils were primarily responsible for providing water supply in the rural areas. Later, Basic Democrats of Union Parishad were involved in the program. Department of Public Health Engineering (DPHE) used to deliver tubewell materials to the Basic Democrats and allocate a lump sum amount as installation cost to carry out installations. This Program could not meet the demand of the community because of absence of appropriate institutional mechanism for quality control in the service delivery and lack of accountability.

Soon after liberation, DPHE was identified to take lead role of water supply delivery in rural areas and a decentralized institutional network up to Thana (Upazila) level was established in early seveties. Site selection committee was formed at Union level with the participation of Union Parishad Chairman and Ward Commissioners to take decision on selection of sites only, while DPHE took the responsibility of installation through contractors.

It was observed through evaluation of the program that community had least control over the quality and cost of installation, only a part of which was borne by the beneficiaries. The cost of tube wells increased over the years and the allocation of tube wells mostly favored the influential community. As a result the program could not reach the low income group in most cases. This situation was more acute in low water table area and coastal belt.

4.5.2 PRESENT SITUATION

It is evident from the preceding chapters that the water supply in the country is now facing a number of challenges from various angles. For the

last decade or more, the efforts of Government, NGOs and donor organizations had succeeded in creating a "water miracle" in Bangladesh that has often been highlighted as a global success. Taking advantage of the shallow water aquifers, and aided by a public sector campaign encouraging people to shift from surface water to ground sources, the introduction of shallow tube-wells enabled 97% of rural households access to "safe" drinking water. The hand pump mounted on tube-wells produced by the private sector and purchased directly by households created, perhaps, the largest private sector supported "safe" drinking water program in South Asia. The arsenic contamination, however, is threatening to undo this success. Unless household level filtering systems become affordable and convenient to use, and preferably easy to link to the shallow tube-wells, the "water miracle" may well be reversed. The arsenic menace has significant bearing on : technological options; financial dimension; and importantly on institutional framework for service delivery.

The broad spectrum of institutional arrangement should be such that it ensures sustainable development. The services that are required, be it technological or financial, need to be delivered optimally. The situation now demands to review and reform the institutional arrangement to address sector issues appropriately. The various technological options appropriate to specific regions, hydrogeological situation, and socio-economic context will have direct relation on financial resource and institutional competence to deliver services.

4.5.3 APPARENT TRANSITION

The drinking water sector institutions and delivery mechanism in Bangladesh are at cross-roads and undergoing major transition. Water supply options that are emerging will find place in line with user choice and preference. In specific geographic units the degree of arsenic contamination may force rural households to shift from individual to community based systems for accessing drinking water. Likewise, in urban areas households depending on non-piped point sources may need to explore alternatives. In both cases financial sustainability will be a major challenge and therefore efficiency of service delivery is of paramount importance today.

Technologies that are alternatives to the shallow tube-well are therefore being explored. Community based systems – as a delivery option now needs to be actively discussed in the policy debate on arsenic mitigation. In many areas, the density of rural settlements in Bangladesh and the growth of rural incomes, and the convenience of the current level of service in the last two decades have created an enabling environment, cost effectiveness and affordability for house connections through network systems. In terms of the arsenic contamination, piped water systems are advantageous over the household level technology because the system can be managed and monitored at one point. Furthermore, the treatment technology can be easily improved/altered centrally as and when better alternatives become available. Finally, a central treatment system also allows for the removal of pathogenic contamination of surface water.

The above scenario calls to re-think on the existing institutional set-up and redefine the roles of communities, private sector, non-government organizations, local governments and the central government. A greater role of local government is envisaged.

The public choice and consumers' welfare issues involved in water quality monitoring and in managing water resources, suggest that local governments need to be directly involved in the arsenic program. These same public choice issues also require that local governments will need to be a partner in the scale-up and sustainability of water systems. A policy pilot, where resources are provided directly to a set of local governments and a source of technical advice through a consortium contracted in from the private sector is made available, may need to be tried out in the current setting of the transitions that are occurring in Bangladesh. Finally even as capacity is contracted in, there would be a need to establish some minimum in-house capacity with Union Parishads (UPs) in financial management and social mobilization to support the political leadership.

This pilot could start in the one district where Union Parishad capacity is already being built up with support from an ongoing project. Once the pilot is implemented, the demonstration effect will familiarize and motivate Union Parishads to scale up their involvement in the public goods dimensions of managing rural services. In this context, Development Partners could assist the Government to look at the design of

a broader capacity process to support the strengthening of local governments.

A series of immediate actions can be undertaken in the 35 Upazillas where BAMWSP has finished screening. As mitigation will start immediately in those Upazillas where over 40% sources have been found arsenic affected:

- set up a National Independent Regulatory Body to vet/certify arsenic removal technologies which will operate without any influence from existing and future players;
- Establish and develop DPHE capacity as Government regulatory body for the water supply and sanitation sector;
- Strengthen DPHE capacity for strategy development, planning, survey investigation, research, monitoring, evaluation and water quality surveillance;
- Strengthen DPHE capacity to provide technical advise, training and HRD;
- Provide training to Upazila and UP staff on arsenic testing by field kits and implementation, operation and maintenance of alternative water supply technologies;
- set up transparent systems at the local level where the Upazilla, Union Parishad (UP) and communities get together and openly share information on options, costs, implementation and management arrangements; and
- provide training on accounting and procurement to UP staff - where such staff is not available deploy private accounting firms to provide this capacity in the short-term, while at the same time they build up capacity in the UP. This training and capacity building should be done by firms based on outcome-based contract.

4.5.4 RATIONALE FOR GIVING A KEY ROLE TO LOCAL GOVERNMENTS

The appropriateness of arsenic mitigation being led at the local level arises first from the principle that local government is the key custodian of local public policy. It is best placed to judge what suits local conditions, provided it has access to information on the range of technology and delivery options. The arsenic situation in rural areas calls for management

of these day-to-day public choice issues as close to the affected people as possible. Critical issues, including repeat screening of arsenic contaminated and non-contaminated sources, sustainability of programs, public education and operation and maintenance of systems are more effectively managed at the local government level. The crisis of coordination and trade-offs with regard to technology-investment choices are best handled at the local government level where a range of options open to communities and are well interfaced with the local government.

Secondly, public subsidies critical to the mitigation efforts need to be managed by the appropriate local institutions to avoid ownership and other long-term management issues. These critical variables require political judgment at the local level.

Arguments that local governments lack capacity, that they are subject to local elite capture and that they are prone to corruption are often articulated in the policy debates about the role of local government. It is clear that political rivalries, corruption, incompetence, ignorance and inadequate resources pose threats to successful program implementation, but this is true of any tier of government and across public-private divide. There is little evidence that involvement of local governments is necessarily more prone to poor governance. Ultimately, it is a question of how decentralization of responsibilities are designed and managed and not a question of decentralization per se. Much of the concerns can be best mitigated through design of checks and balances.

The same principles apply on the issue of capacity. Experience shows that capacity does not grow independently of responsibility. Indeed, there is a potential synergy between growth of capacity, decentralization of responsibilities with authorities, and building accountability of local governments. The design issue is therefore to support this synergy by providing a mechanism which will support local government capacity building .

4.5.5 ROLE OF COMMUNITIES, PRIVATE SECTOR AND NGOS

A critical element in this approach is the role of NGOs and how they interface with local government, communities and central government, when the technology for arsenic mitigation goes beyond the realm of the household into one where village/community level public policy decisions need to be made. The extent of central or local government involvement in NGO arsenic mitigation programs is likely to increase if community water supply schemes are to be scaled up.

NGOs, working with the community and Union Parishads (UPs), would help to set up local service providers serving one or two villages. The NGO would work to mobilize community groups and help them develop local water utilities which could be run on either profit or non-profit basis. User charges should cover at least the Operations and Maintenance charges and replacement costs of equipment such as pumps.

4.5.6 ROLE OF CENTRAL GOVERNMENT

The Local Government Division (LGD) of the Ministry of Local Government, Rural Development and Co-operatives (MLGRD&C) is the nodal Government unit for the sector. Its recently established National Forum for Water Supply and Sanitation should be fully operational with requisite resources and skills to manage the entire sector needs. The Unit for Policy Implementation (UPI) which is supporting the LGD should be mainstreamed as the analytical body for the LGD. The LGD needs to effectively co-ordinate its different management and implementation organizations including the Pourashavas, the City Corporations, the Water and Sanitation Authorities in Dhaka and Chittagong, Local Government Engineering Department (LGED) and the nodal technical organization DPHE.

The Public Sector Agency, DPHE, which is the lead technical organization responsible for supporting the LGD and the Local Governments in planning, delivery and management of the sector, requires a serious thrust towards water supply regulations, planning, research, monitoring and surveillance in order to provide technical oversight for the sector. There is

a need for building DPHE's capacity as Government regulatory body for the water supply and sanitation sector. It's capacity needs to be strengthen for strategy development, planning, survey investigation, research, monitoring, evaluation and water quality surveillance.

4.5.7 A FRAMEWORK FOR CAPACITY BUILDING OF LOCAL GOVERNMENT

It is quite clear that involvement of local governments in service delivery, arsenic mitigation and supporting a scale-up of community water systems would require a capacity building framework. The principles for such a program involve four elements: assigning clear responsibilities and revenues; establishing capacity support windows; providing incentives to build up capacity; and finally establishing a monitoring and evaluation mechanism of the process.

First, local governments must have clear expenditure assignments and a clear source of predictable funds to undertake the responsibility. In this case, funds for arsenic screening and mitigation would form the entry point. In the future, for example, BAMWSP project funds can be converted to programmatic funds for local governments.

Second, local governments should have access to grant funding to "buy-in" capacity as and when needed. This "demand window" recognizes that capacity needs will have to be defined in the local context in a dynamic fashion—in different phases of the implementation of the arsenic mitigation program local governments will need different forms of capacity. As these needs emerge, local governments should have access to a rapid response fund to acquire the capacity form the market.

Third, local governments should have access to a "supply window". This window recognizes that there are some fundamental systems of financial management, planning, social mobilization and other parameters are the pre-requisite for a good local government system. Mobile teams from special resource centers comprising these needed skills would serve clusters of local governments to help build up the basic systems of financial management, planning etc. Such supply side teams would also assist local governments to access the demand window, if needed.

Fourth, there should a be "fiscal incentive" window which would reward those local governments that have been able to use the demand and supply windows of support to reach certain milestones in delivery (in this case arsenic mitigation or piped water implementation) and of setting up the basic local government financial management systems.

Finally, a M&E system needs to be developed by the upper tier government to ensure constant learning from on the ground reality. It also ensures a check and balance that is needed to impose a culture of accountability.

Applying these windows to the case of the arsenic mitigation program, the following approach may be considered. A *National Capacity Building System* (NCBS) could be set up in Bangladesh that would operate under two systems – a *supply based system* where it would be funded up front to develop demonstration projects in different UPs which could then be replicated. The demonstration project would also include UP capacity building so that eventually they may spread them across the union. Instead of pilots a plan for national support through mobile teams could also be tested. The second would be a *demand-based system* where the NCBS would operate on demand from unions for help.

The incentive to have local governments use the capacity support could be delivered through a challenge fund. A challenge fund could also be developed to provide an incentive for local governments to come up with innovative mechanisms to manage community water supply systems using independent service providers.

4.6 CONCLUSIONS

4.6.1 Alternative Water Supply Options

Safe water supply in arsenic contaminated areas is a priority to avoid arsenic poisoning. Uncontaminated shallow tubewells will continue to be the sources of safe drinking water supply for 75 million rural and urban population even in arsenic affected areas for years until these tubewells are found contaminated. The national screening program for identification of arsenic contaminated tubewells should be completed as soon as possible. A regular water quality monitoring and surveillance program is also required to be installed to observe the possible change in arsenic content of these safe shallow tubewells. Alternative water supply systems would replace the contaminated tubewells and those turn out to be subsequently contaminated during monitoring to maintain the present level of water supply coverage.

Preliminary estimation presented in this paper shows that about 29 million people exposed to arsenic contamination in excess of 50 µg/L will require alternative safe water supplies. The available alternative options are area dependent and have their relative advantage and disadvantages. Hence, no single option can serve the purpose or respond to the needs of the people having different social and economic conditions. The following alternative options may be considered for water supply in the arsenic affected areas.

Deep Tubewell

Deep tubewells may be installed to avoid shallow arsenic contaminated aquifers where suitable arsenic safe deep aquifers are available to produce water of acceptable quality for water supply. Manually operated deep tubewells are source of safe and reliable water supply in many parts of the coastal area. The manually operated deep tubewlls have very low draw-down and insignificant impact on hydraulics of deep aquifers. It is important to first delineate the areas where such deep aquifers are

available that are separated from shallow contaminated aquifers by relatively impermeable layers. The bore holes of the deep tubewells are required to be sealed at the level of impermeable strata to avoid percolation of arsenic contaminated water. An aquifer formed by oxidized coarse reddish sands appears to be safe for installation of tubewells. Hydrogeological investigations are needed to delineate suitable deep aquifers and ascertain the mechanism of recharge and possibility of contamination of these aquifers.

Piped Water Supply

Piped water supply having advantages over tubewells can very easily replace existing shallow tubewell based water supplies. Piped water supplies for all domestic purposes may be costly for low income group of people. On the other hand, piped water system would be technically inconvenient and costly for scattered rural population living in flood plains. Piped water supply is a potential solution to arsenic problem in the following areas.

- In an urban center with piped water supply, the people dependent on shallow tubewells in the fringe areas can be brought under piped water supply through expansion of existing areas of service coverage. Piped water supply should also be introduced in the urban centers fully dependent on shallow tubewells. Arsenic removal would be required for the few urban centers having arsenic contaminated production wells. The iron-cum-arsenic removal plants installed in some towns should work well to make water safe for drinking when the contamination levels are low to moderate. Thus a population of 16.86 million presently served by shallow tubewell can be provided with arsenic safe piped water supply in the urban centers in Bangladesh.

- Piped water supplies are also possible for clustered households in villages, growth centers and the rural areas having good rural network.

- Arsenic safe water for piped water supplies may be available from any sources such as deep tubewell, treated surface or arsenic contaminated water or water from community dug wells.

Treatment of Surface Waters

Surface water is arsenic safe but invariably contains impurities of greater immediate health concerns. Surface water requires treatment for desired level of clarification and disinfection. Protected sources make treatment easier and a unprotected source requires elaborate treatment for removal of impurities of different origins. Most importantly, the surface water sources must be perennial and availability of such sources may be difficult in many places.

- Slow sand filters like pond sand filters (PSFs) are suitable for surface water if turbidities remain within 30 ppm. The requirement for frequent washing of filter media resulting from filtration of water of high turbidities is the main reason for abandoning many existing PSFs in Bangladesh. However, pretreatment by roughing filtration can overcome these difficulties. Community participation in operation and maintenance is absolutely essential to make the system work.

- Pressure filtration through sand bed followed by disinfection can be installed where power supply is available. It requires technical supervision but availability of water of desired quality is assured.

- Conventional treatment plants can be scaled down as per requirement for the treatment of surface waters for relatively larger communities. It will require skilled personnel for operation and maintenance.

Dug Well

Dug wells may be constructed where feasible for arsenic safe water supplies. The areas with aquifers at shallower depth and the hilly areas are suitable for the construction of dug wells. The areas with thick consolidated clay layers like the Madhupur and Barind tracts are not suitable for dug well construction. A larger diameter dug well installed in favorable aquifer can be used for community water supplies. Sanitary

protection and careful monitoring of water quality are essential components of dug well based water supplies. Unstable soil conditions in many places will require lining or side protection, which will make system expensive. There are also construction difficulties in the wet season when water table rises up.

Rainwater Harvesting

Rainwater harvesting has good potential for water supply in arsenic and salinity affected areas in Bangladesh. People need motivation to adopt this system of water supply. Because of the requirements for large catchment areas and storage tank due to unequal distribution of rainfall throughout the year, rainwater harvesting should be a household option and designed to meet the demand for drinking and cooking water only. The catchment area and storage tank need standardization in relation to rainfall intensity and distribution in Bangladesh.

Treatment of Arsenic Contaminated Water

Removal of arsenic from contaminated water for drinking water supplies has drawn remarkable attention in recent years. Some units developed for treatment of arsenic at household and community levels and installed for experimental use in different parts of Bangladesh have shown very good potentials for use in water supply in arsenic affected areas. Relatively higher costs and management of arsenic rich waste products are yet to be addressed. However, prospective technologies are being evaluated under Environmental Technology Verification program in Bangladesh.

4.6.2 Research and Development Needs

There are many areas of research and development in diverse fields of alternative water supplies in Bangladesh. Some of them are listed below:

- Analysis of water supply situation including population exposed to arsenic contamination based on updated data available from on-going studies.

- An evaluation of effectiveness, impact and replicability of arsenic mitigation initiatives in Bangladesh.

- Study of surface water treatment plants in operation in Bangladesh: identification of problems and possible solutions for application in the design of alternative surface water based water supply technologies.

- Leaching characteristics of arsenic rich sludges under different conditions and possible contamination from arsenic rich effluents produced by arsenic removal technologies.

- Effect of sanitary protections on arsenic content of dug well water.

- Development of construction, operation and maintenance manuals for each of the following:

    - Rainwater harvesting
    - Dug wells
    - Small scale surface water treatment
    - Piped water supply

- Development of an accurate and reliable field kit for measurement of arsenic at the village level.

- Development of effective, affordable and environment friendly arsenic removal technologies for use in rural areas of Bangladesh.

- Mechanism of recharge of deep aquifers and possibility of contamination of deep tubewells.

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5. LIST OF PARTICIPANTS OF TECHNICAL SESSIONS

5.1 HEALTH GROUP

Name	Address
Ahmad, Sk. Akhtar	Associate Professor, Dept. of Environmental & Occupational Health, NIPSOM, Dhaka.
Ahsan, Habibul	Assistant Professor of Epidimology & Principal Investigator, Arsenic Chorot Study in Bangladesh, Columbia University, New York, USA
Alam, M. N .	Chairman, Dept. of Medicine, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh
Alauddin, Mohammad	Department of Chemistry, Wagner College, NY 10301, USA
Ali, Amzad	Consultant, HLSP/Management Change Unit, MOHFW, Bangladesh.
Barbhuiya, M. A. Khalique	Head, Dept. of Environmental & Occupational Health, NIPSOM, Dhaka, Bangladesh
Begum, Shamsun Nahar	Directorate General of Health Services, Dhaka, Bangladesh
Caussy, Deoraj Harry	Regional Epidemiologist, WHO South East Asia Regional Office, New Delhi, India
Correll, Ray	CSIRO, Australia

Dey, Ranjit Kumar	Director, Planning, Research & Environmental Health, Directorate General of Health Services, Dhaka, Bangladesh.
Faruquee, M. H.	Asia Arsenic Network, Dhaka, Bangladesh
Haque, M. Mujibul	Head, Dept. of Dermatology, Dhaka Medical College, Bangladesh
Haque, Md. Abidul	Assistant Professor, Dept. of Biostatistics, NIPSOM, Dhaka, Bangladesh
Heijnen, Han	WHO Environmental Advisor, Dhaka, Bangladesh
Hossain, A. Z. M. Zahid	Consultant (Urologist), Dhaka Medical College, Bangladesh
Hossain, Md. Zakir	Medical Officer, Planning Unit, Directorate General of Health Services, Bangladesh
Inaoka, Tsukasa	Dept. of Public Health, University of Kumamoto, Japan
Islam, A. B.M. Azizul	Assistant Director, Directorate General of Health Services, Bangladesh
Islam, Badrul	Director, Institute of Epidemiological Disease Control and Research, Dhaka, Bangladesh
Islam, Maidul	Chairman, Dept. of Dermatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh
Jahan, Miskat Ara Akhtar	Senior Scientific Officer, Bangladesh Council for Scientific and Industrial Research, Dhaka, Bangladesh
Karim, Enamul	Epidemiologist & Consultant, Management Change Unit, MOHFW,Bangladesh

Kaufmann, Rachel	Senior Public Health Specialist, CDC / World Bank Liaison for Environmental Health, The World Bank, Washington DC
Kawahara, Kazuyuki	Expert, Japan International Cooperation Agency, Dhaka, Bangladesh
Khan, M. A. Wadud	Head, Dept. of Community Medicine, NIPSOM, Dhaka, Bangladesh
Khan, Manjur ul Hoque	Medical Officer, Dept. of Environmental & Occupational Health, NIPSOM, Dhaka, Bangladesh
Khan, Saima	Research Analyst, The World Bank, Dhaka
Khyyam, Syed Umar	Deputy Program Manager, Planning Unit, Directorate General of Health Services, Bangladesh
Mazumder, D. N. Guha	Principal Investigator of Arsenic Research, Head, Dept. of Medicine & Gastroenterology (Retd.), Institute of Post Graduate Medical Education and Research, Kolkata, India
Milton, Abul Hasnat	Chief, Arsenic cell, NGO Forum for Drinking Water Supply & Sanitation, Dhaka, Bangladesh
Mohammad, A. K. M. Ghulam	Professor, Radiotherapy, Dhaka Medical College, Bangladesh

Mollah, Md. Nurul Haque	Deputy Program Manager, Occupational Health, Directorate General of Health Services, Bangladesh
Momin, Abdul	Associate Professor, Dermatology, Dhaka Medical College, Bangladesh
Murshed, Rubaiul	Research Fellow, Australian National University
Quamruzzaman, Quazi	Chairman, Dhaka Community Hospital, Dhaka, Bangladesh
Rabbani, G. H.	Bangladesh Arsenic Control Society, ICDDR,B Dhaka
Rahman, Mahmudur	Coordinator, Dhaka Community Hospital, Dhaka, Bangladesh
Rahman, Md. Siddiqur	Deputy Program Manager, Arsenic Unit, Directorate General of Health Services, Dhaka, Bangladesh
Rahman, Sk. Matiur	Proshika, Dhaka, Bangladesh
Rashid, Harun-Ar	Director, Bangladesh Medical Research Council, Bangladesh
Ratnaike, Ranjit	Associate Professor of Medicine, University of Adelaide, Dept. of Medicine, The Queen Elizabeth Hospital, Australia
Saha, K.C.	Former Head, Dept. of Dermatology, School of Tropical Medicine, Kolkata, India

Sayed, M. H. Selim-ullah	Assistant Professor, Dept. of Environmental & Occupational Health, NIPSOM, Dhaka, Bangladesh
Shah, Md. Aminur Rahman	Program Manager, Environmental Health, Directorate General of Health Services, Bangladesh
Shreshta, Kokila	Division of Epidemiology, Ministry of Health, Nepal
Siddique, F. M.	Associate Professor of Medicine, Dhaka Medical College, Bangladesh
Sim, Malcolm	Associate Professor and Head, Unit of Occupational and Environmental Health, Department of Epidemiology and Preventive Medicine, Monash University, Australia
Smith, Allan H.	School of Public Health, University of California, USA
Tarafder, S. A.	Director, Bangladesh Atomic Energy Commission
Wahidi, M. O. K.	Dhaka Community Hospital, Bangladesh
Wilson, Richard	Harvard University, USA
Zaman, Sabrina	UNICEF, Dhaka, Bangladesh

5.2 HYDROGEOLOGY GROUP

Name	Address
Abdullah, S. K. M.	Former Director General, Geological Survey of Bangladesh
Acharya, Subhrangsu Kanta	Former Director General, Geological Survey of India, Kolkata
Ahmed, Chowdhury Mufad	Senior Assistant Secretary, Local Government Division, Ministry of LGRD & Cooperatives, Bangladesh
Ahmed, Kazi Motinuddin	Associate Professor of Geology, University of Dhaka, Bangladesh
Alam, A K M Khorshed	Deputy Director, Geological Survey of Bangladesh, Bangladesh
Alam, Md. Khurshed	Superintending Engineer, Department of Public Health Engineering, Bangladesh
Arif, Taufiqul	World Health Organization, Bangladesh
Bashar, Khairul	Chairman, Dept. of Geological Sciences, Jahangirnagar University, Bangladesh
Begum, Nasima	Assistant Director, Geological Survey of Bangladesh
Bhattacharya, Prosun	Research Coordinator, Ground Water Arsenic Research Centre, Royal Institute of Technology, Sweden
Boerschke, Roy	Program Coordinator, OCETA, Dhaka
Chappell, Willard R.	University of Colorado at Denver, USA

Chatterjee, Debashis	Ground Water Arsenic Research Group, University of Kalyani, India
Chilton, John	Hydro-geologist, British Geological Survey
Chowdhury, Abdul Quader	Project Director, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Chowdhury, Md. Lutfar Rahman	Geologist and Additional Secretary (OSD) Government of Bangladesh
Cullen, Willum R.	University of British Columbia, Canada
Geen, Alexander van	Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University, USA
Halim, M. A.	Member (Hydrogeology), Bangladesh Agriculture Development Corporation
Haque, Imamul	Professor, Dept. of Soil Science, University of Dhaka, Bangladesh
Hoque, Monirul	Professor, Department of Geology, University of Dhaka, Bangladesh
Hasan, Kamrul	Environment Agency, Birmingham, UK
Hossain, Alamgir	Director, Groundwater, Bangladesh Water Development Board
Hossain, Md. Munir	Hydrogeologist, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Hossain, Sazzad	Professor, Dept. of Geology, University of Dhaka, Bangladesh
Islam, A. K. M. Shamsul	Chief Engineer, Bangladesh Water Development Board, Dhaka

Islam, M. Nazrul	Director General, Geological Survey of Bangladesh, Dhaka
Islam, Shafiqul	Professor, Department of Civil and Environmental Engineering, University of Cincinnati, USA
Kabir, Babar N.	Program Coordinator, Sustainable Environmental Management Program, Ministry of Environment & Forest, Bangladesh
Khaliquzzaman, M.	Consultant, The World Bank, Dhaka
Khan, Aftab Alam	Associate Professor, Department of Geology, University of Dhaka, Bangladesh
Khan, Nurul Islam	Executive Engineer, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Kinniburgh, David	Principal Scientist, Hydrochemist, British Geological Survey, U.K.
Majumder, Ratan Kumar	Geologist, Bangladesh Atomic Energy Commission, Dhaka
Mosihuzzaman, M.	Professor, Dept. of Chemistry, University of Dhaka, Bangladesh
Nishat, Ainun	Country Representative, IUCN, Bangladesh
Noor, Md. Abdun	Executive Engineer, Department of Public Health Engineering, Bangladesh
Nurunnabi,	Geologist, DANIDA, Dhaka, Bangladesh
Poddar, B.C.	Center for Study of Man & Environment, Parivesh Kendra, Kolkata, India
Rahman, Hafizur	Ureka House, Dhaka, Bangladesh

Rahman, Mizanur	Geologist, Bangladesh Water Development Board
Ravenscroft, Peter	Consultant Hydrogeologist, U.K.
Scheinder, Verne	US Geological Survey, USA
SenGupta, Pradip Kumer	Director, Geological Survey of Bangladesh (GSB), Dhaka
Shakya, Kishore	Regional Director of DWSS of Central Region, DWSS, Nepal
Shibasaki, Naoaki	Hydrogeologist, JICA Study Team in Bangladesh
Sultan, Syed Tipu	Secretary General, International Farakka Committee, USA
Swann, Peregrin	DFID, Bangladesh
Uddin, Md. Nehal	Deputy Director, Geological Survey of Bangladesh, Dhaka
Wees, Huub Van	Economic Affairs Officer, Environment and Natural Resources Development Division, Thailand
Welch, Alan H.	Research Hydrologist, US Geological Survey
Wells, Brian	CIDA, Canada

5.3 ALTERNATIVE WATER SUPPLY GROUP

Name	Address
Adeel, Zafar	Academic Program Officer, Environment and Sustainable Development, The United Nations University, Tokyo, Japan
Ahmad, Junaid	Regional Team Leader, Water and Sanitation Program – South Asia, The World Bank, New Delhi, India
Ahmed, Aminuddin	Former Chief Engineer, Department of Public Health Engineering, Dhaka, Bangladesh
Ahmed, Farooque	Professor, Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka
Ahmed, Kazi Nasiruddin	Former Additional Chief Engineer, Department of Public Health Engineering, Dhaka
Ahmed, M. Feroze	Professor, Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka
Ahmed, Saiful Azam	Country team Leader,a.i, Water & Sanitation Program, The World Bank, Dhaka, Bangladesh
Ahsan, Tanveer	Urban Specialist, Water & Sanitation Program, The World Bank, Dhaka
Akhter, Abeda	Senior Assistant Secretary, Local Government Division, Bangladesh
Akter, Nargis	WaterAid, Dhaka, Bangladesh
Ali, Reshad Md.	Deputy Director, Geological Survey of

Ekram	Bangladesh, Dhaka
Azad, Abu S.	Disaster Forum, Dhaka
Azam, Kazi Ali	Executive Engineer, Department of Public Health Engineering, Dhaka, Bangladesh
Badruzzaman, A.B.M.	Professor, Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh
Baral, J. K.	Proshika, Dhaka, Bangladesh
Choudhury, W. R.	Rotary Club of Dhaka, Dhaka, Bangladesh
Chowdhury, J. T. A.	Hydrochemist, Bangladesh Arsenic Mitigation Water Supply Project. Dhaka
Collard, Reg. V.	Adviser Water Supply, Rotary International, Australia
Davis, Collin	Chief, WES Section, UNICEF, Dhaka
Dewan, M. Jahir Uddin	Assistant Engineer, Department of Public Health Engineering, Dhaka, Bangladesh.
Dyer, Rodney	DFID Manager (Water and Sanitation), UNICEF, Dhaka
Farooque, M. K.	Joint Director, Department of Environment, Bangladesh
Gondolf, Preben	Counselor, Royal Danish Embassy, Dhaka, Bangladesh
Haider, S. Z.	Professor (Rtd.), Dept. of Chemistry, University of Dhaka
Haque, Md. Nurul	Director, Aqua Consultants & Associates Ltd., Dhaka, Bangladesh

Herath, Nell	Helvetas, 21 Remond Road, Nugegoda, Srilanka
Hoque, Md. Mofazzal	Project Coordinator, Community Based WSS Project, Department of Public Health Engineering, Dhaka, Bangladesh
Hoque, Rashedul	Executive Engineer, Department of Public Health Engineering,, Dhaka, Bangladesh
Hossain M. Ali	Professor, Independent University of Bangladesh, Dhaka
Huq, Ihtishamul	Executive Engineer, R & D Division, Department of Public Health Engineering, Dhaka, Bangladesh
Ibrahim, Md. A. K. M.	Executive Engineer, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Islam, A. B. M. Ashraful	Executive Engineer, Local Government Engineering Department, Dhaka, Bangladesh
Islam, Aminul	UNDP, Dhaka, Bangladesh
Islam, Md. Shafiqul	WES Section, UNICEF, Dhaka, Bangladesh
Islam, Sylvia	CIDA, Dhaka, Bangladesh
Jalil, M. A.	Professor, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka
Kabir, A. B. M. Ziaul	Program Officer, Unit for Policy Implementation, Local Government Division, Bangladesh
Karim, Mir Fazlul	Deputy Director, Geological Survey of Bangladesh, Dhaka

Khan, Ehteshamul Rashid	Assistant Engineer, Department of Public Health Engineering, Dhaka, Bangladesh.
Kittu, N.	OSD, Rajib Gandhi National Drinking Water Supply Mission, Ministry of Rural Development, India
Mahmud, Shamsul Gafur	Executive Engineer, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka, Bangladesh
Martin, Paul J.	Environmental Specialist, The World Bank, Dhaka, Bangladesh
Matin, M. A.	Joint Director, Rural Development Academy Bogra (RDAB), Bangladesh
Miah, Farid Uddin Ahmed	Former Project Director, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka, Bangladesh
Miah, Md. Abdur Rahman	Senior Deputy Director, NILG, Dhaka, Bangladesh
Minnatullah, K. M.	Senior Water and Sanitation Specialist, Water & Sanitation Program, The World Bank, Dhaka, Bangladesh
Motaleb, Abdul	Director, WATSAN Partnership Project, Dhaka, Bangladesh
Murshid, Sarmeen	BROTEE, Bangladesh
Muslim, S. M. Abu	Chief Engineer, Department of Public Health Engineering, Dhaka, Bangladesh
Nath, Tapan K.	WHO-DPHE Healthy Cities Program
Neku, Amer	Engineer in charge of Arsenic Mitigation Program Division of Water Quality Control, DWSS, Nepal

Nuruzzaman, M.	Environmental Specialist, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Quadir, Razia	Managing Director, Dharitri, Dhaka, Bangladesh
Rafiqunnabi,	Executive Engineer (P&C Div), Department of Public Health Engineering, Dhaka, Bangladesh
Rahman, Md. Mujibur	Professor, Civil Engineering Department, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh
Rahman, Md. Mustafizur	Executive Engineer, Training Division, Department of Public Health Engineering, Dhaka, Bangladesh
Rashid, Harun Ur	Consultant, Unit for Policy Implementation, Local Government Division, Ministry of LGRD & Cooperatives, Bangladesh
Rashid, S. M. A.	Executive Director, NGO Forum for Drinking Water Supply and Sanitation, Dhaka, Bangladesh
Riad, Imam Mahmud	Assistant Engineer, Bangladesh Arsenic Mitigation Water Supply Project, Dhaka
Rojario, Gabreal	WES Section, UNICEF, Dhaka, Bangladesh
Rosenboom, Jan-Willem	Project Officer, WES(Arsenic), WES Section, UNICEF, Dhaka, Bangladesh
Salam, Abdus	NGO-Forum for Drinking Water Supply &Sanitation, Bangladesh
Sarker, Gulbahar	World Health Organization, Bangladesh

Shamsuddin, Sk. Abu Jafar	Centre Manager, International Training Network (ITN) Centre, Dhaka, Bangladesh
Shrestha, Raj Babu	Rural Water Supply and Sanitation Fund Development Board, Nepal
Smith, Meera	Project Well, West Bengal, India
Takaku, Keiichi	Expert, Japan International Cooperation Agency, Bangladesh
Tsushima, Sachie	Country Representative, Asia Arsenic Network, Bangladesh
Uddin, Ziya	Watsan Project, Care Bangladesh, Dhaka