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Arsenic 2000

An Overview of the Arsenic Issue in Bangladesh

DRAFT FINAL

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PURPOSE

WaterAid Bangladesh has prepared this report to provide an overview of the arsenic issue in Bangladesh primarily for agencies, organisations and individuals who are not water sector specialists and who want an informed summary of current knowledge on:

- *the background to the arsenic contamination issue*
- *the potential scale of the problem*
- *the work of 35 organisations active in arsenic mitigation*
- *the instrumentation methods for the detection of arsenic*
- *the arsenic mitigation options*
- *the way forward*

In addition, a primary objective of the document is to promote co-ordination and information sharing between organisations and to highlight the need for prompt action with regard to arsenic mitigation.

Much of the required information for immediate arsenic mitigation interventions is available, but collation of inter-agency data is urgently required, as is a pro-active approach to the development of a timely, national mitigation strategy.

WaterAid Bangladesh and its partner organisations in Bangladesh intend to disseminate the collated information in various formats and languages, with a particular focus on participatory information media for NGOs supporting communities affected by arsenic contamination.

WaterAid intends that this report will be built upon with further sections on the chemistry of arsenic in groundwater and new mitigation technologies as they emerge from research and testing, plus regular updates on arsenic mitigation programmes' progress and learning.

ACKNOWLEDGEMENTS

The documentation would not have been possible without the active participation and input of the majority of the 35 organisations who willingly supplied detailed information on their programmes' arsenic activities.

The author would like to offer special thanks to Han Heijnen, Ross Nickson, David Sutherland, Nasir Uddin and Karin Heissler for their support and advice during the documentation of this report.

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1.0 Introduction

As a result of a large effort by Government, donors and NGOs over the last twenty years an estimated 97% of drinking water in Bangladesh is now supplied by groundwater, this was considered one of the most effective public health measures in the country. Tubewells have, in the majority, replaced the traditional surface water sources and diarrhoeal disease has reduced significantly.

In the early 1990s high arsenic concentrations were reported in the groundwater of Nawabgonj, western Bangladesh. There has been a large amount of debate with reference to the source and release mechanism of the arsenic. It is now widely accepted that it is of natural, geological origin. The arsenic is thought to be closely associated with iron oxides. The release mechanism of arsenic from the sediments into the groundwater is hotly debated. Evidence exists to support both reduction and oxidation theories.

Every round of water quality tests show more wells that exceed the Bangladesh standard of 50 parts per billion (ppb) for arsenic in drinking water. The equivalent of ppb is micrograms/litre or ìg/l. The World Health Organisation (WHO) guideline value for arsenic in drinking water is 10ppb. Measuring arsenic in water accurately is not simple at concentrations important for human health. Reliable field methods are yet to be fully developed and evaluated. A protocol for marking unsafe tubewells red (greater than 50ppb of arsenic) and safe tubewells green (less than 50 ppb of arsenic) has been widely adopted.

Today an estimated:

- 25 million people are exposed,
- 59 out of 64 districts have arsenic contaminated ground water,
- 249 out of 464 upazilas are affected and
- over 7000 patients have been identified.

Every day more cases of arsenosis are reported in the media. Arsenic in water is invisible and has no taste or smell. Health effects from consuming arsenic-contaminated drinking-water are delayed. Skin lesions are generally first. The most important remedial action is the prevention of further exposure by providing safe drinking water. Grave concern exists for future health effects and the number of people affected by arsenic poisoning. Malnutrition and Hepatitis B, both of which are prevalent in Bangladesh, accentuate the effects of arsenic poisoning. Three stages of arsenicosis symptoms (primary, secondary and tertiary) are described in Annex 1.

Long-term ingestion of high concentrations of arsenic from drinking water gives rise to a number of health problems, particularly skin disorders, the most common are pigmentation changes (dark/light skin spots) and keratosis (warty nodules usually on the palms and soles of feet). Internal cancers have been linked with arsenic in drinking water. Many of the advanced and more serious clinical symptoms are incurable. Arsenicosis is not contagious.

Community level arsenic awareness and knowledge is generally low. Information, Education and Communication (IEC) materials have been and are being developed. Mass media and grass roots participatory education tools are an important aspect of an holistic arsenic mitigation strategy.

There is a clear need for safe water options and a co-ordinated approach to the arsenic issue. The current situation is such that numerous Governmental departments, donors, NGOs, development banks and academic institutions are involved in the technical and social issues relating to arsenic contaminated groundwater. Documentation of who is doing what where is not readily accessible. This report briefly summarises the activities of various organisations in the hope of increasing co-ordination, information sharing and thus the effectiveness of the collaborative inputs. Further clarification on specific points relating to organisations' activities should be addressed to the concerned organisation.

Ongoing updates to this report will be necessary.

2.0 Background

2.1 Summary of origin and scale of the problem

It is now generally agreed that the arsenic contamination of groundwater in Bangladesh is of geological origin. The arsenic derives from the geological strata underlying Bangladesh. The arsenic is thought to be closely associated with iron oxides. Arsenic occurs in two oxidation states in water. In reduced (anaerobic) conditions it is dominated by the reduced form: arsenite. In oxidising conditions the oxidised form dominates: arsenate.

There are two main theories as to how arsenic is released into the groundwater:
Pyrite oxidation. In response to pumping, air or water with dissolved oxygen penetrates into the ground, leading to decomposition of the sulphide minerals and release of arsenic.
Oxyhydroxide reduction. Arsenic was naturally transported in the river systems of Bangladesh adsorbed onto fine-grained iron or manganese oxyhydroxides. These were deposited in flood plains and buried in the sedimentary column. Due to the strongly reducing conditions which developed in the sediments and groundwater of certain parts of Bangladesh the arsenic was released into groundwater.

The release mechanism is still hotly debated but the second theory is thought to be the more likely explanation.

Natural processes of groundwater flushing will eventually wash the arsenic away but this will take thousands or tens of thousands of years. The flushing is particularly slow in the Bengal Basin in general because it is so large and flat.

Local variations in the rate of groundwater movement due to the location of rivers and variations in topography or type of sediment (clay, silt or sand) probably account for much of the local variation. Natural processes of sedimentation and sediment transport create variations in the arsenic problem within the Bengal Basin, e.g. greater concentration in South East Bangladesh.

The British Geological Survey (BGS) national survey (3500 samples) found that 27% of shallow tubewells exceeded the 50 $\mu g\ L^{-1}$ (50ppb) Bangladesh arsenic standard. Comparable statistics for the WHO guideline value (10 $\mu g\ L^{-1}$ or 10ppb) show that 46% of shallow wells exceeded the value (Kinniburgh & Smedley, 2000).

The spatial distribution of arsenic concentrations above 50ppb in the BGS second phase survey showed district basis variations from 90% of sampled wells in Chandpur to none in the eight north-western districts.

Predicting exactly which wells are affected is difficult at the village scale and a strategic aim must therefore be to measure all or most of the wells in Bangladesh for arsenic. There are approximately 4.5 million public (installed by Government departments) and a total 9 million tubewells in Bangladesh. An estimated 97% of the Bangladesh population of 120 million drink well water. Until the discovery of arsenic in groundwater, well water was regarded as safe for drinking. Piped water supplies are available only to a small portion of the total population.

In some areas, the deep aquifer and shallow dug wells may provide reliable long-term sources of groundwater for drinking but a strategy for protecting the deep aquifer would be essential.

The BGS results indicated that there were no other groundwater quality problems on a comparable scale to arsenic although there are quite common exceedances of WHO health-related standards for manganese, boron and uranium.

3.0 Current Activities

3.1 Department of Public Health Engineering (DPHE)

DPHE is one of the key departments under the Ministry of Local Government Rural Development and Co-operatives (LGRD&C). DPHE has a number of different arsenic activities at various levels of implementation and is working with a wide variety of development organisations.

A summary of the DPHE arsenic activities follows. Further details are contained under the partner and / or supporting organisations.

3.1.1 Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP)

BAMWSP is the National co-ordinating project for arsenic issues relating to water supply. Its US$44.4million budget is co-financed by Government of Bangladesh (GoB), World Bank and Swiss Agency for Development and Co-operation (SDC). BAMWSP aims to co-ordinate arsenic interventions and through its National Arsenic Mitigation Information Centre (NAMIC) collect, collate and disseminate arsenic information from and to interested or active organisations. The project was formally launched September 1998 for a period of four years. To date 6% of funds have been disbursed.

The BAMWSP Technical Advisory Group (TAG) consists of an eight strong panel of experts who, at the request of BAMWSP, advise on technical issues such as alternative drinking water sources, field test kit specifications and arsenic removal technologies. Currently the TAG have recommended the following arsenic mitigation measures:

- Pond Sand Filter
- Deep Tubewell
- Rainwater Harvesting
- Hand -dug Well
- Three Kolshi Arsenic Removal Technology

Included in the mandate of BAMWSP is the emergency activity of screening all tubewells within six upazilas, this has been completed. BAMWSP are currently testing various arsenic removal technologies and alternative drinking water sources.

Longer-term objectives incorporate the identification of all arsenic affected thanas and the full tubewell screening and arsenic mitigation of 40 upazilas. BAMWSP aims to co-ordinate and direct other developmental organisations to arsenic affected upazilas in an effort to minimise duplication and maximise the effectiveness of the combined activities.

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3.1.2 DPHE Research & Development Division

The Research and Development Division (R&DD) of DPHE have been instrumental in a number of large and small-scale arsenic initiatives.

These include a field test kit survey of 21,000 tubewells and mapping the extent of arsenic contamination; testing arsenic removal technologies and alternative options; implementing mitigation measures; training DPHE field staff in use of arsenic field test kits

DPHE / British Geological Survey (BGS) / Mott MacDonald Ltd carried out a rapid investigation into groundwater studies for arsenic contamination of all thanas (except in the Chittagong Hill Tracts) which identified the extent of arsenic contaminated groundwater within Bangladesh. Phase one included the compilation, review and database of existing groundwater and sediment arsenic data from Bangladesh; a systematic groundwater quality survey using laboratory analysis for the 41 districts then believed to be worst affected in Bangladesh; a detailed geochemical investigation in three special study areas; modelling the movement of groundwater and arsenic in a typical Bangladesh situation. Phase two continued from Phase one and extended the survey to the remaining districts of Bangladesh excluding the three districts of the Chittagong Hill Tracts. All information is available on both DPHE and BGS web sites *www addresses*.

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3.1.3 DPHE / UNICEF

The DPHE / UNICEF arsenic mitigation initiative to date has consisted of several National-scale activities and a focussed 'Action Research' project in five upazillas.

The national-scale activities undertaken include testing of 51,000 tubewells in 1998 using field test kits to give the first idea of the scale of contamination Nationwide and the development and testing of a comprehensive communication campaign including radio and television spots.

The 'Action Research into Community Based Arsenic Mitigation' project has worked in five upazillas with BRAC (two upazillas), Grameen Bank, Dhaka Community Hospital Trust and the Integrated Service for the Development of Children and Mothers (ISDCM - with Rotary Funding). The project followed an integrated approach and included four main activities: communication about arsenic and arsenicosis; testing of all tubewells in the upazilla; arsenicosis patient identification / support / implementation; monitoring and evaluation of alternative water supply technologies. The technologies tested ranged from home-based solutions such as the 3-kolshi arsenic removal filter to community-based solutions such as the Pond Sand Filter (PSF) for treatment of surface water.

DPHE / UNICEF are currently developing the second phase of the project which has similar activities with further emphasis placed on sustainability, community involvement and community cost sharing. The phase two project is planned to work in 15 upazillas.

Three out of the fifteen upazillas will be funded by the UN Foundation. This project will be undertaken jointly with the WHO and will include a research component, which will be handled by the WHO.

DFID is the main funder of a US$ 49.3million five year Rural Hygiene, Sanitation and Water Supply Project, implemented by DPHE with assistance from UNICEF. The water supply component is primarily aimed at low water table and underserved areas in 38 districts of Bangladesh. It is not specifically targeted at arsenic-affected areas but measures will be taken to ensure that all water supplies provided are free from arsenic. Implementation is expected to commence early in 2001, on completion of the inception phase.

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3.1.4 DPHE / World Health Organisation (WHO)

The WHO Environmental Health Team in Bangladesh has supported the Government of Bangladesh since the early stages of recognition of the arsenic problem (1994), mostly by providing technical expertise. This expertise included both technological aspects of arsenic removal and an epidemiological review of the health effects and immediate actions required for mitigation.

As a result in 1997, WHO acknowledged that arsenic in drinking water was a "Major Public Health Issue" which should be dealt with on an "Emergency Basis". Joint studies with local institutes have been carried out to test household arsenic removal techniques and the quality of alternative drinking water sources. An evaluation was made of the field test kits available (1998). WHO has been an active partner to Government and in the context of interagency collaboration, through the organisation of a National Co-ordination conference, support for various aspects of arsenic mitigation, and through the management of an interlaboratory comparison exercise aimed at improving capacity of local laboratories to determine arsenic contamination in water. Partners include other UN agencies such as UNICEF, the World Bank, IAEA, UNIDO and the FAO.

WHO have been involved in an informal Emergency Arsenic Taskforce which has documented an emergency action approach and funded a geographical information system (GIS) mapping of arsenic hotspot villages and working areas of various arsenic projects (see appendix 3). This information is held by NAMIC who are responsible for updating the maps.

WHO have been instrumental in encouraging best practice and inter-agency co-ordination.

WHO and UNICEF will shortly start a two-year action research project on arsenic mitigation in three upazillas, with funding from the UN Foundation. In addition to funding direct mitigation activities the project will monitor interventions and determine their usefulness in recipient populations, review the earlier UNICEF five-upazilla project for health impacts and analyse the arsenic health effects in the MATLAB health and population research area of ICDDRB.

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3.1.5 DPHE / DANIDA

The DPHE/DANIDA Arsenic Mitigation Component aims to work within the visions of arsenic mitigation as expressed in the objectives of the National policy.

These are:
- Facilitating the access of all citizens to arsenic free water
- Bringing behavioural changes necessary for ensuring continued use of arsenic free water for drinking and cooking
- Reducing the incidence of arsenic poisoning
- Building capacity in local governments and communities to deal more effectively with arsenic related problems
- Awareness creation and promoting sustainable arsenic mitigation options
- Promoting the use of surface and rainwater in order to reduce the intake of arsenic contaminated water

Learning from their previous one year pilot project the approach is planned to be replicated in 11 thanas (Bakergonj, Banaripara, Barisal sadar, Ujirpur under Barisal district, Pirojpur sadar under Pirojpur district, Sonagazi under Feni district, Lakshmipur sadar, Raipur, Ramgati under Lakshmipur district, Begumgonj, Noakhali sadar under Noakhali district).

The activities and outputs to date have included:
Project orientation, baseline survey, screening of all tubewells; training of trainers for the staff members and other stakeholders, development of IEC materials, awareness creation; development and implementation of the Bucket Treatment Units (BTU), fill and draw (F&D), three kolshi as arsenic removal technologies; testing of alternative treatment technologies; safe water supply through the installation of deep tubewells, mini pipe schemes and rainwater harvesting; Geographical Information System (GIS) mapping, data base and inventory of tubewells; assessment of field test kit reliability; equipping and running one laboratory in Noakhali. The total budget for the DPHE/DANIDA Arsenic Mitigation Project is approximately US$ 9million.

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3.2 Ministry of Health and Family Welfare (MoHFW)

In 1996 a National Steering Committee for Arsenic Mitigation related activities was formed and headed by the Honourable Minister for Health and Family Welfare. The mandate of this Steering Committee was formulation of policies, endorsement of programmes, monitoring and co-ordination of activities related to the arsenic contamination. The committee is scheduled to convene every three-months. The Cabinet Secretary, Secretaries of all concerned ministries and Heads of all concerned government departments, local and overseas agencies have been included in the membership of the committee.

The MoHFW, with GoB Funding, have completed the following projects and activities: a Technical Assistance Project (approximately US$100,000) from February 1997 to June 1998 implemented in seven districts concentrating on patient identification and treatment. Source water was tested for arsenic concentrations. Community awareness programmes were initiated using appropriate communication materials. All health personnel of the project districts were trained in patient identification and treatment. A total of 3200 patients were identified. A similar project (approximately US$16,000) was undertaken in Chapa Nawabganj district where 400 arsenic affected patients were identified.

An eight-month UNDP funded emergency programme for arsenic mitigation (US $0.5 million) was implemented in the worst effected 200 villages of 20 districts. This project was a combination of survey and technology option testing. All tubewells in these villages were tested for arsenic and painted red or green accordingly. A GIS (Geographical Information System) was developed to identify the hot spots on a pilot basis. Arsenic removal technologies were tested. Information Education & Communication (IEC) activities were implemented. The programme was conducted through a GO-NGO approach under supervision of the MoH&FW. The results showed that 62% of the tubewells in these 200 villages were found arsenic polluted and 0.3% of the total population was found to show symptoms of arsenic poisoning.

A Phase-II US$1.2 million UNDP funded emergency programme was completed June 2000 in 300 villages. The project aimed at providing immediate relief to the 300 most affected villages in Bangladesh. The project objective was to identify patients, test and mark all tubewells, identify and provide the best option for arsenic free water; and follow-up on the status of villages in which interventions had been carried out in Phase 1.

All works were contracted out to appropriate agencies for implementation under the supervision of Deputy Programme Manager (Arsenic), MoH&FW.

In addition, from July 1999, MoH&FW has developed a treatment protocol and Information Education Communication (IEC) activities. MoH&FW with UNICEF funding have trained 1600 doctors and 7000 health workers for case identification.

To date more than 9000 patients have been identified with visible signs of arsenicosis through MOH&FW managed initiatives.

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3.3 Department of Public Health Services / UNICEF

UNICEF have supported DPHS and Dhaka Community Hospital Trust to develop a patient treatment protocol and in training doctors and health workers in 80 districts across the country. DPHS and UNICEF are working together to build capacity of public health workers to identify and treat patients.

The health division of UNICEF also supports the following activities:

- Active patient identification in UNICEF working areas by house to house screening
- Compilation of a patient profile with all related information such as - biological investigation results (including nail and urine) water information, sign-symptoms etc.

- Disseminate patient lists to relevant organisations, so that alternate options are prioritised to the areas with most patients.
- Distribute medicine (anti-oxidants and skin ointment) to the identified patients.
- Nationwide training of doctors and health workers through DGHS.
- Establish a referral and surveillance system with collaboration from DGHS and DCHT (link patient with alternate water options in addition to treatment facilities)
- Collaboration with CDC for epidemiological studies.
- A planned collaboration study with DCHT to see efficiency of different treatment options for the patients.

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3.4 Ministry of Water Resources (MoWR)

The National Water Management Plan Project (NWMPP) has submitted a Draft Development Strategy (DDS) to the Water Resources Planning Organisation (WARPO).

The NWMPP recognises the urgent need for arsenic-free domestic water supplies, but sets the problem in the context of the 25-year planning horizon. This context envisages:

- A raising of arsenic standards by GoB to match existing WHO standards of 10ppb
- Increased faecal contamination of static surface sources and the shallow aquifer
- Increased agri-chemical contamination as farmers try to raise yields to meet a 44% decline in arable land/capita
- Expansion of areas where water tables fall below the suction limit of Village Handpumps (VHP) for water supply and Shallow Tubewells (STW) for irrigation in the dry season, as irrigation continues to expand
- Increased vulnerability to drought due to global warming, slight in an average year but dramatic in a dry year.
- An increase in living standards and demands from women for household access to water and improved services and a need to reduce the time spent in queues for water.

The DDS notes that Deep Tubewells (DTWs) are a potential solution, but are expensive to provide for small groups. Even with a Tara pump they serve approximately 100 people with limited supplies. DTW fitted with small (1kW, 1 litre/sec) submersible pumps could supply 50 lcd piped water supply to 1000 people through a 50mm diameter distribution system for an average cost of $4Tk/m^3$. The option meets criteria of quality, sustainability, affordability and implementability.

The DDS recognises than before such systems can be advocated on a large scale, field testing of the concept is needed. The total cost to the Government of Bangladesh for 120 million people is estimated at US$450 million.

DDS notes that Dhaka is in an area relatively free of arsenic, but if the current expansion south and east continues, the risk will increase, as falling water tables will draw in water from greater distances. An aqueduct conveying $20m^3/s$ of water from the Jamuna Bridge, where the minimum flow is $6000m^3/s$, may appear to be an option which is cost effective.

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3.5 World Bank

The US$44.4million National level Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) is co-funded by GoB, World Bank and SDC. In August 1998 World Bank approved credit of US$32.4million to GoB to implement the four-year project. To date 6% of funds have been disbursed. BAMWSP (see section 3.11) aims to co-ordinate arsenic interventions and through its National Arsenic Mitigation Information Centre (NAMIC) collect, collate and disseminate arsenic information from and to interested or active organisations. BAMWSP's Project Management Unit (PMU) is headed by DPHE. BAMWSP is task managed by the World Bank Dhaka office.

The World Bank Dhaka office is planning to distribute over 100,000 household level arsenic removal technologies through their Nationwide nutrition programme. Information will be disseminated as to patient identification, treatment and referral mechanisms.

World Bank has funded various workshops on technical issues relating to safe water sources. World Bank has been involved in the organisation of photograph exhibitions in an attempt to raise the profile of arsenic in drinking water.

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3.6 Swiss Agency for Development and Co-operation (SDC)

SDC, with GoB and World Bank, is co-funding the US$44.4million National level Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP). In August 1998 World Bank approved credit of US$32.4million to GoB to implement the project. BAMWSP (see section 3.11) aims to co-ordinate arsenic interventions and through its National Arsenic Mitigation Information Centre (NAMIC) collect, collate and disseminate arsenic information from and to interested or active organisations. BAMWSP's Project Management Unit (PMU) is headed by DPHE.

The WATSAN Partnership Project (see section 3.22) is SDC funded and is a collaborative community based rural water supply, sanitation and hygiene sector project currently undertaken in Rajshahi and Chapai Nawabgonj Districts. The problem of arsenic contamination in ground water has necessitated investigation and implementation of affordable new technologies for the most severely affected people in the project area.

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3.7 Canadian International Development Agency (CIDA)

CIDA are currently funding a three year (2000/2003) Environmental Technology Verification (ETV-AM) - Arsenic Mitigation Project. The project works closely with the Technical Advisory Group (TAG) and BAMWSP (see section 3.11) and is implemented though the Ministry of Local Government, Rural Development and Co-operatives, Local Government Division and Ontario Centre for Environmental Technology Advancement (OCETA). The CIDA contribution to the project is approximately US$2.7million.

The objective of the project is to develop a transparent process for assessing and verifying arsenic removal technologies and the transfer of the process and procedures to an entity designated by the Government of Bangladesh. The main outputs will include internationally recognised criteria for examining arsenic removal technologies; a process for certification of arsenic removal technologies and confirmed technology viability through a comprehensive field verification program.

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3.8 Department for International Development (DFID)

DFID have funded numerous initiatives on the arsenic issue. These include a two phased approach by DPHE / British Geological Survey (BGS) / Mott MacDonald Ltd. Phase one included the compilation review and database of existing groundwater and sediment arsenic data from Bangladesh; a systematic groundwater quality survey using laboratory analysis for the 41 districts then believed to be worst affected in Bangladesh; a detailed geochemical investigation in three special study areas; modelling the movement of groundwater and arsenic in a typical Bangladesh situation. Phase two continued from Phase one and extended the survey to the remaining districts of Bangladesh excluding the three districts of the Chittagong Hill Tracts. All information is available on both DPHE and BGS web sites *www addresses*.

The Rapid Assessment of Household level Arsenic Removal Technologies is a DFID funded initiative. The study is jointly managed by WaterAid Bangladesh and DFID and implemented by WS Atkins International Ltd. The consultancy will focus on nine household level arsenic removal technologies with a first phase concentrating on field testing technical parameters and a second phase of technical and social parameter testing. The project will feed its rapid response results into longer-term initiatives in Bangladesh. Canadian CIDA (section 3.7) are supporting a substantial intervention in partnership with Bangladeshi agencies and will assist BAMWSP to develop an Environmental Technology Verification (ETV) protocol. The DFID consultancy will work closely with BAMWSP and the development of the ETV protocol, use the ETV protocol (at draft stage) and give feedback through field testing of the ETV protocol. A spin-off benefit of this DFID funded study will be the comparative evaluation of the Merck, GPL, HACH, NCL and PeCo75 arsenic field test kits (see section 4.1 for details on field test kits). Phase one results are expected late 2000.

DFID will fund an Arsenic Mitigation and Epidemiology Project implemented by Dhaka Community Hospital Trust, with technical support from the London School of Hygiene and Tropical Medicine. The three-year project will have an approximate budget of US$3million. The three-month inception phase is planned to commence November 2000. The main components of this project would focus on the assessment of community based arsenic mitigation models using socio-epidemiological methods. The goal of the project is to reduce, using an affordable, sustainable and community integrated programme, both the incidence and prevalence of arsenic related ill health in Bangladesh.

DFID is the major funder of a US$ 49.3million five year Rural Hygiene, Sanitation and Water Supply Project, implemented by DPHE with assistance from UNICEF. The water supply component is primarily aimed at low water table and underserved areas in 38 districts of Bangladesh. It is not specifically targeted at arsenic-affected areas but measures will be taken to ensure that all water supplies provided are free from arsenic. Implementation is expected to commence early 2001, on completion of the inception phase.

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3.9 Japan International Co-operation Agency (JICA)

JICA are funding a Study Team to investigate groundwater development of deep aquifers for safe drinking water supply to arsenic affected areas in Western Bangladesh. The main objective of the study is to prepare a master plan to cope with arsenic contamination of groundwater.

Three model purshavas and villages have been selected to carry out detailed pilot testing which includes the following activities: household interviews on socio-economic conditions, arsenic test of tubewells, drilling of deep wells, performance and testing of arsenic removal equipment and core boring.

JICA are also supporting an interlaboratory comparative study which will work closely with the WHO initiative.

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3.10 Australian Aid (AusAID)

AusAID has recently launched the Australian Arsenic Mitigation Program which has a total budget of US$1.6 million. In June 2000 proposals were requested from Bangladesh, India and Australia in a public tender.

Implementation will commence January 2001, subject to approval from partner governments. The three activities include:

- A research project looking at methods of using iron ore to extract arsenic from water. (Orissa, India)
- A cross sectoral activity with Dhaka Community Hospital Trust (DCHT) which will review methods for providing Bangladesh with safe and clean water and then pilot several of these methods in a number of villages in conjunction with health education. The activity will also upgrade the laboratory at DCHT to enable more sophisticated water quality testing
- An epidemiology study that will consider the cost of arsenic mitigation in Bangladesh and train representatives of the NGO Forum for Water Supply and Sanitation.

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3.11 United States State Department

The U.S. Geological Survey (USGS) and Geological Survey of Bangladesh (GSB) are conducting a collaborative investigation of the conditions and processes controlling the high arsenic concentrations in ground water. USGS activities are planned for three more years with support provided by the U.S. State Department. USGS and GSB scientists will work to analyse samples of soil, sediment and water to describe the solid-phase residence of arsenic and the chemical transformations that release the arsenic to the water. Solid-phase samples will be collected from excavations and boreholes. Water samples will be gathered by installing wells at multiple depths in the immediate vicinity of the boreholes so that the correspondence of the solid and water composition can be evaluated. The initial effort is focussed in eastern Bangladesh in the vicinity of Brahmanbaria and Comilla. Plans for 2001 include collecting samples from depths up to 300 meters with the intent of determining the composition of sediments in the “deep” aquifer and documenting differences that may account for the apparent low levels of dissolved arsenic in water extracted from greater depths.

The goal is to develop an understanding of the sources and sinks of arsenic in the sediment and integrate this result with sedimentology and hydrology. Future work will be at other locations on the Bengal delta (including India) with the intent of adding to efforts of other research teams and co-operatively developing a unified explanation of controls on dissolved arsenic.

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3.12 Water and Sanitation Programme (WSP) Bangladesh

The WSP is involved in the promotion of best practice in the water and sanitation sector, co-ordination of sector activities and the provision of support to government in policy formulation and implementation.

WSP work closely with World Bank water and sanitation team and were involved in the preparation of BAMWSP. WSP activities include technical support to BAMWSP (section 3.11) management and technical support to pilot projects and innovative approaches, organization of arsenic workshops and conferences.

WSP currently chairs the Local Consultative Group (LCG) on water supply and sanitation. The LCG is the Donors' Co-ordination forum which is scheduled to meet monthly.

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3.13 United Nations Development Programme (UNDP)

Through the Ministry of Health & Family Welfare (MoHFW) UNDP have funded an initial eight month emergency programme for arsenic mitigation (US $0.5 million) which was implemented in the worst effected 200 villages of 20 districts. This project was a combination of survey and technology option testing (see section 3.2). The programme was conducted through a GO-NGO approach under supervision of the MoH&FW.

UNDP funded the Phase-II emergency programme US$1.2 million which was completed June 2000 in 300 villages. The project aimed at providing immediate relief to the 300 most affected villages in Bangladesh. The project objective was to identify patients, test and mark all tubewells, identify and provide the best option for arsenic free water; and follow-up on the status of villages in which interventions had been carried out in Phase 1.

All works were contracted out to appropriate agencies for implementation under the supervision of Deputy Programme Manager (Arsenic), MoH&FW.

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3.14 Rotary International

Rotary Clubs are working jointly with UNICEF in combating the problem of arsenic contamination in ground water. Overseas Rotary Clubs have been assisting local Rotary Clubs with funds. Arsenic mitigation activities include installation and assessment of safe water options. The main options promoted are installation of arsenic-free deep tubewells, construction of continuous arsenic removal plant, rainwater harvesting, pond-sand-filter and dug wells.

Additional activities include tubewell screening, identification of arsenicosis patients, development of Information, Education and Communication (IEC) materials. The areas covered to date are Manikganj, Behra, Kachua, Sonargaon and Gunarkacha.

The Rotary Foundation has recently awarded a Grant of US$ 500,000 for an arsenic mitigation project in Bangladesh. The work on this Project will commence in the near future.

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Contact: David Alexander
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3.15 Arsenic Crisis Information Centre (ACIC)

The West Bengal & Bangladesh Arsenic Crisis Information Centre was founded in 1997 and is based in Dhaka. ACIC is a private not-for-profit service focusing on enhancing the visibility and accessibility of arsenic crisis related information using Internet technologies. Currently it maintains:

- A website at http://bicn.com/acic
- An opt-in email newsletter (680 subscribers currently) to announce when new information is added to the website (email acic-subscribe@listbot.com to subscribe)

- Three moderated email discussion groups at egroups.com,

(1) arsenic-source, for those interested in all aspects of arsenic geochemistry (email arsenic-source-subscribe@egroups.com to subscribe);

(2) arsenic-safewater, for those interested in water treatment technologies and alternative supplies (email arsenic-safewater-subscribe@egroups.com to subscribe); and

(3) arsenic-medical, for those interested in arsenic disease diagnosis, epidemiology, treatment of symptoms, etc. (email arsenic-medical-subscribe@egroups.com to subscribe)

ACIC was an individual effort until October 2000, when a student intern was hired, funded in part by subscriber voluntary donations. Currently an office is being set up and NGO registration is being prepared. Funding will then be sought to support improvement and expansion of the information services offered.

ACIC is keenly interested in supporting and cooperating with other organizations, networks, websites, publications, etc., and actively seeks suggestions from stakeholders on how to improve its information services and what new information services should be set up to better serve the community.

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3.16 Dhaka Community Hospital Trust (DCHT)

DCHT, a private sector, not-for-profit institution, has contributed significantly towards raising arsenic awareness at Government and international level and have alerted the general public to the incidence of arsenicosis.

In 1999 DCHT completed a UNDP/WB funded survey (Rapid Assessment Project - RAP) in 200 villages on behalf of MoH&FW, to verify the extent of contamination and arsenicosis. Using its own resources, DCHT has also completed a country-wide sampling survey of tubewell water and found evidence that 41 of a total of 64 districts could be at risk. DCHT undertook an extension to the RAP, within a further 300 villages. This study was managed and executed through MoH&FW (section 3.2), UNDP funded and completed June 2000.

DFID will fund an Arsenic Mitigation and Epidemiology Project implemented by DCHT, with technical support from the London School of Hygiene and Tropical Medicine. The three year project will have an approximate budget of US$3million. The three-month inception phase is planned to commence November 2000. The main components of this project would focus on the assessment of community based arsenic mitigation models using socio-epidemiological methods. The goal of the project is to reduce, using an affordable, sustainable and community integrated programme, both the incidence and prevalence of arsenic related ill health in Bangladesh. To develop and assess the success of community based mitigation models by using scientific epidemiological processes. In additional the project will add to epidemiological knowledge of prevalence and dose response of arsenic poisoning in Bangladesh.

AusAID will fund a cross sectoral activity with Dhaka Community Hospital Trust which will review methods for providing Bangladesh with safe and clean water and then pilot several of these methods in a number of villages in conjunction with health education. The activity will also upgrade the laboratory at DCHT to enable more sophisticated water quality testing.

DCHT, in collaboration with NGO Forum, Village Education Centre and WaterAid Bangladesh, have undertaken small scale arsenic action research into the effectiveness of community mobilisation and information systems.

DCHT have organised international conferences on arsenic and are involved in on going advocacy efforts.

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3.17 PROSHIKA

PROSHIKA, under three separate joint ventures, has imported simple and sustainable arsenic mitigation technologies from Canada, Belgium and Germany to combat arsenic contamination in groundwater.

PROSHIKA state that the three technologies, already commissioned in various parts of the arsenic contaminated areas of the country yielded satisfactory results through ensuring supply of arsenic free drinking water and also prevention of various water-borne diseases.

PROSHIKA and Canadian International Water Purification Limited (CIWPL) have entered into an agreement for manufacturing of low-cost water purifiers for household use both in urban and rural areas of Bangladesh. The aim of the Canadian Water Purifier (CWP) is to effectively remove arsenic as well as parasites, bacteria and viruses from water. The joint venture project of manufacturing household level water filters has been installed in Palashbari, Savar, production has commenced.

Under another joint venture agreement with ALTECH of Belgium, PROSHIKA has installed a surface water treatment plant at Patgram in Tungipara and safe water from surface water can be treated. Each such plant (approximate cost US$16,000) can produce 1500 Litre of water per hour and is estimated to meet the demands of approximately 500 families. PROSHIKA has signed a new agreement with ALTECH to set up a factory in Bangladesh for the production of Surface Water Treatment Plants. All the accessories of the plant will be produced in Dhaka.

PROSHIKA has signed a separate agreement with SIDKO Limited of Germany. "Continuous Shallow Ground Water Arsenic Removal Plants" have been installed at Chapai Nawabganj and Bhanga.

PROSHIKA has been creating awareness among its target beneficiaries about arsenic contamination, safe water and measures to be taken for preventing health affects of arsenic.

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3.18 BRAC

BRAC, is one of the largest national non-governmental organisations and has a proven capacity for field-level programme implementation, socio-economic research, a strong institutional network and experience in training of community members in testing tubewell water for arsenic.

BRAC initiated arsenic mitigation activities through testing all 802 tubewells in its field offices. 12% were found to be arsenic contaminated.

In Hajiganj upazilla 93% of the 11,954 tubewells tested by BRAC in this upazilla showed the presence of arsenic. When the results of field testing by Village Health Workers (VHW) were cross-checked with laboratory results 93% were consistent. The testing program in Hajiganj upazilla was completed in just over a month.

In 1998 BRAC completed a countrywide testing of tubewells, which were installed by the Department of Public Health Engineering (DPHE) during 1997-1998 with assistance from UNICEF. A total of 12,604 tubewells were tested under this project using field kits. It took 35 days to complete the testing.

In 1999 BRAC, in collaboration with UNICEF and DPHE, initiated a pilot project on community-based arsenic mitigation in one union of Sonargaon upazilla under Narayanganj district The project followed an integrated approach and included four main activities: communication about arsenic and arsenicosis; testing of all tubewells in the upazilla; arsenicosis patient identification / support / implementation; monitoring and evaluation of alternative water supply technologies. The technologies tested ranged from home-based solutions such as the 3-kalshi arsenic removal filter to community-based solutions such as the Pond Sand Filter (PSF) for treatment of surface water

In June 1999 BRAC extended the action research on community-based arsenic mitigation to two upazillas: Sonargaon of Narayanganj district and Jhikargacha of Jessore district. Working closely with DPHE/UNICEF, BRAC actively involved communities in assessing and mitigating the arsenic crisis.

Once tubewells have been tested for arsenic BRAC then involve communities in highly affected areas in finding alternative sources of safe drinking water. This project attempted to test different options of safe drinking water in the two upazillas. As very little was known about the effectiveness and acceptability of different safe water options at the beginning of the project, it was essentially an ‘action research’ to assess the different options.

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3.19 Grameen Bank

Grameen Bank, with assistance from UNICEF and DPHE (see section 3.1.3), started its testing programme in 1997 in Chandpur district. The project followed an integrated approach and included four main activities: communication about arsenic and arsenicosis; testing of all tubewells in the upazilla; arsenicosis patient identification / support / implementation; monitoring and evaluation of alternative water supply technologies. The technologies tested ranged from home-based solutions such as the 3-kalshi arsenic removal filter to community-based solutions such as the Pond Sand Filter (PSF) for treatment of surface water.

Arsenic Research Group [BD] is conducting an action-research project on arsenic contamination in the rural setting of Bangladesh, funded by PRPA of Grameen Trust.

The target village is located in Comilla.

Screening of tube-wells was carried out using the NIPSOM field test kit and the tube-wells were marked with specified colours, i.e. red for contaminated tube-wells (arsenic content >50ppb), and green for safe tube-wells (arsenic content <50ppb)] . Water from only 12 (twelve) out of total 159 tube-wells in the village were found to be below 50ppb.

A communication campaign was carried out by meeting with different sections of the community, group discussions, house to house visits by researchers and field assistants in order to build up public awareness on the arsenic contamination related problems.

The 2nd phase survey was carried out to record the population and tube-wells on a household basis and to identify the households and/or population served by individual tube-wells. The objective of carrying out this survey was to identify the extent of contamination in the specified area and the population at risk.

A few patients were identified but no detailed health screening was carried out.

The oxidant and coagulant based 'Emergency arsenic removal unit's [a modified two bucket system with reverse circulation] are currently undergoing the final phase of field trials. A 'Pond Sand Filter [PSF]' and two 'Sanitary Dug-Wells' will be installed in the village.

The Arsenic Research Group is involved in the development of a ceramic/earthenware based low cost surface water purifier under the direct supervision of Mr. Reid Harvey.

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3.20 WaterAid Bangladesh

WaterAid Bangladesh is actively involved in both the grassroots level arsenic screening, mitigation and small scale research (through their national NGO partner organisations) and advocacy of best practice and co-ordination at policy level.

To assist the promotion of easily understandable, appropriate and reliable information dissemination to communities and field workers involved in and affected by arsenic a formal partnership between NGO Forum for Drinking Water & Sanitation (see section 3.28) and WaterAid Bangladesh exists. The NGO Arsenic Information and Technical Support Unit (NAISU) will commence early 2001.

The NAISU target information group is an important aspect of the approach as the aim is to ensure understanding of the cause, effect and mitigation measures of arsenic in groundwater. The target group will include communities, field workers and office workers. These target groups require different levels of information presented in an appropriate format. In order to reach the broadest possible network the NGO Forum regional offices will have access to information via email, telephone and the postal service.

NAISU's immediate objectives are to reach out and support small to medium sized NGOs across Bangladesh who are trying to understand the issues surrounding arsenic contamination of water supplies and support them to assist their beneficiaries to address and tackle these issues. NAISU will also develop and disseminate layman’s (easily understood) Bangla and English language material and training to a target population of non-technical community and field workers.

WaterAid Bangladesh have developed two sets of participatory arsenic awareness tools (see Annex 6) which encourage discussion and understanding at community level.

WaterAid Bangladesh and Village Education Resource Centre (VERC) are working together in the piloting of arsenic removal technologies, screening and mitigation in their project areas of Sitakunda and Nawabgonj.

Village Education Resource Centre (VERC) in collaboration with WaterAid Bangladesh, DCHT and NGO Forum have undertaken small-scale arsenic action research into the effectiveness of community mobilisation and information systems.

WaterAid Bangladesh support and advocate the local manufacture of field test kits through field user feedback and comparative evaluations.

WaterAid, working in collaboration with British Geological Survey (BGS), have developed a six page Arsenic Fact Sheet (see Annexe 5) summarising the health effects, occurrence in groundwater, field testing methodologies and remediation techniques.

WaterAid Bangladesh have been involved in an informal Emergency Arsenic Taskforce which has documented an emergency action approach (Annexe 8) and funded a geographical information system (GIS) mapping of arsenic hotspot villages and working areas of various arsenic projects (see Annex 3). This information is held by NAMIC who are responsible for updating the maps.

The Rapid Assessment of Household level Arsenic Removal Technologies is a DFID funded initiative. The study is jointly managed by WaterAid Bangladesh and DFID and implemented by WS Atkins International Ltd. The consultancy will focus on nine household level arsenic removal technologies with a first phase concentrating on field testing technical parameters and a second phase of technical and social parameter testing. The project will feed its rapid response results into longer-term initiatives in Bangladesh. Canadian CIDA (section 3.7) are supporting a substantial intervention in partnership with Bangladeshi agencies and will assist BAMWSP to develop an Environmental Technology Verification (ETV-AM) protocol. The DFID consultancy will work closely with BAMWSP and the development of the ETV protocol, use the ETV protocol (at draft stage) and give feedback through field testing of the ETV protocol. A spin-off benefit of this DFID funded study will be the comparative evaluation of the Merck, GPL, HACH, NCL and PeCo75 arsenic field test kits (see section 4.1 for details on field test kits). Phase one results are expected late 2000.

WaterAid Bangladesh actively encourages information sharing.

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3.21 Village Education Resource Centre (VERC)

VERC are actively involved in the tubewell screening and development of community led arsenic mitigation strategies and approaches.

VERC and WaterAid Bangladesh are working together in the piloting of household level arsenic removal technologies, tubewell screening, community awareness raising and community led mitigation activities in their project areas of Sitakunda and Nawabgonj.

VERC in collaboration with DCHT, NGO Forum and WaterAid Bangladesh have undertaken small scale arsenic action research into the effectiveness of arsenic mitigation approaches reliant on community mobilisation and information systems, not the provision of infrastructure.

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3.22 WATSAN Partnership (WPP)

The WATSAN Partnership Project (WPP) is a collaborative community based rural water supply, sanitation and hygiene sector project currently being implemented in Rajshahi and Chapai Nawabgonj Districts of Bangladesh. The Swiss Agency for Development and Co-operation (SDC, section 3.6), being the initiator and funder, has brought together a partnership of local and international agencies for strengthening and accelerating development activities in the rural areas. In this partnership project, SDC is a member of the steering committee which is chaired by the three International NGOs on a rotational basis. The main role of the Project Management Unit (PMU) is to co-ordinate activities amongst partners.

The three international NGOs: CARE, IDE, and DASCOH act as support organisations to facilitate the development of local organisational capacities in working towards sustained water use and better sanitation for the rural community. NGO-Forum is also conducting an action research on rainwater harvesting in three of the working areas under WPP.

The primary objective of the project is to improve user's sustainable access and use (i.e. hygiene behaviour practices) of affordable water and sanitation facilities in the project area, especially in the low water table area of Bangladesh. The problem of arsenic contamination in ground water has necessitated investigation and implementation of affordable new technologies for the most severely affected people in the WPP area.

To mitigate the arsenic problem, WPP has started to work with arsenic reduction technologies and alternative safe water sources. The arsenic reduction options tested are: DPHE / DANIDA Bucket Treatment Unit (BTU), the three kolshi method, Safi Filter and SORAS (see Annexe 9). The alternative water source options are rainwater harvesting, dugwells (with handpump and without handpump) and SODIS (Solar Disinfection, see Annexe 7) for improving the bacteriological water quality. All these technologies are new in the project area and some are still at the research stage.

Development and marketing of affordable handpumps is one of the major activities of WPP. IDE have developed an affordable deep-set Jibon handpump for the low water table area. Reliable Pre and Post testing of water quality (arsenic) is a pre-requisite for successful implementation of the WPP deep-set handpump tubewell programme.

This program will be completed by 31st December 2001.

Currently, WPP is preparing a program for arsenic awareness, screening, patient identification, community development and mitigation planning for 640 villages in collaboration with all partners.

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3.23 CARE Bangladesh

The arsenic activities of CARE Bangladesh are associated with three projects. The WATSAN Partnership Project in Rajshahi, Nawabganj (WPP, see section 3.22) the Flood Proofing Project in Kurigram, Netrokona (FPP) and the Sanitation And Family Education Resource project in Sitakunda, Chittagong (SAFER).

The field test kits used are the NIPSOM and E-Merck kits with some cross-checking by the arsenator and laboratory. WPP do not paint the tubewells themselves but inform the community of the results and explain the relevance. Within both the SAFER and FPP tubewells are painted red or green.

Within the WPP, before the sinking of new tubewells, staff carry out an assessment of the surrounding area. Pre and post installation arsenic testing and develop a system of periodic testing.

CARE mitigation activities include the three kolshi, DPHE/DANIDA bucket treatment unit, community based training and practical demonstrations, community based arsenic removal plants (SIDCO, see Annexe 10), monitoring of technologies, protected dug wells, rainwater harvesting, SODIS (see Annexe 7) and SORAS (see Annexe 9), participatory Information Education & Communication (IEC) materials, folk songs and drama sessions.

CARE believes in sustainability through cost sharing with the community. There is no blanket policy for percentage as it is dependent on circumstance and users' feedback.

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3.24 Bangladesh University for Engineering and Technology (BUET)

The Environmental Engineering Division of BUET is currently working on:

(1) development of a domestic arsenic removal unit based on activated alumina
(2) improvement of the two-bucket unit using ferric chloride as a coagulant and
(3) development of a domestic arsenic removal unit based on iron coated sand.

BUET has an extensive array of arsenic measurement equipment including AASGF, AASHG, SDDC units and Field Test kits.

International Training Network (ITN)-Bangladesh Centre for Water Supply and Waste Management at BUET have been involved in the development of Arsenic Field Test Kits, evaluation of the performance of Pond Sand Filters (PSF) and Rainwater Harvesting as alternative sources of water supply. ITN are involved in training on arsenic at tertiary level.

In addition M. Feroze Ahmed, Professor of Civil/Environmental Engineering, BUET is an active member of the BAMWSP Technical Advisory Group (section 3.11).

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3.25 University of Dhaka

The University of Dhaka has undertaken a number of arsenic related research works within the Department of Geology, the Department of Soil, Water and Environment and the Department of Chemistry. These are summarised under the relevant departments below. A detailed list of the research papers produced features as Annexe 2.

Department of Geology

Arsenic Investigation in the Bengal Delta Plain of Bangladesh and hydrogeological research into:

- i) The origin and Distribution of Arsenic in Central Bangladesh 1997
- ii) The occurrence and distribution of Arsenic in Meherpur 1998
- iii) The occurrence and distribution of Arsenic in Chowmohani 1999

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Department of Soil, Water and Environment

The department runs a joint ACIAR (Australia)-Dhaka University project on the "Transfer of Arsenic in water-soil-plant systems in Bangladesh and Australia". The project duration is initially for a period of three years extendable to five years. The department is working on the arsenic load from irrigation water to the soil and its subsequent transfer to the human body and other biological systems through the food chain.

Relationships between the nutritional status of a patient and the manifestation of the contamination are being studied. Some statistical models on the whole system are being produced. The Australian team leader is Dr. RAVI NAIDU from CSIRO, Adelaide. The co-partners in the project are DCHT and INFS, Dhaka University, those in Australia are Ballarat University, CMIS, Adelaide.

The laboratory at the Department of Soil, Water and Environment is equipped with AAS hydride generator to analyse Arsenic in ppb levels.

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Department of Chemistry
Research and development of the three kolshi household level arsenic removal technology in collaboration with the Sono Diagnostic Center Environment Initiative.

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3.26 International Development Enterprises (IDE)

IDE are involved in both the technical and the social mobilisation aspects of arsenic mitigation. IDE are one of the three international NGOs managing the WATSAN Partnership Project (WPP, see section 3.22). The primary objective of the project is to improve user's sustainable access and use (i.e. hygiene behaviour practices) of affordable water and sanitation facilities in the project area, especially in the low water table area of Bangladesh. The problem of arsenic contamination in ground water has necessitated investigation and implementation of affordable new technologies for the most severely affected people in the WPP area. To mitigate the arsenic problem, WPP has started to work with arsenic reduction technologies and alternative safe water sources. The arsenic reduction options tested are: Bucket Treatment Unit (BTU), the three kolshi method, Safi Filter and SORAS (see Annexe 9). The alternative water source options are rainwater harvesting, dugwells (with handpump and without handpump) and SODIS (Solar Disinfection, see Annexe 7) for improving the bacteriological water quality. All these technologies are new in the project area and some are still at the research stage.

Development and marketing of affordable handpumps is one of the major activities of WPP. IDE have developed an affordable deep-set handpump named the Jibon for low water table areas. Reliable Pre and Post testing of water quality (arsenic) is a pre-requisite for successful implementation of any deep-set handpump tubewell program.

IDE are independently experimenting with alternative source technologies which include a ceramic filter to treat surface water and economic designs of rainwater harvesting tanks.

IDE have produced two short videos which are shown around the country to increase arsenic awareness at a local level.

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3.27 World Health Organisation (WHO)

In response to the arsenic crisis the WHO Task Force dealing with the WHO Guidelines for Drinking-water Quality have given priority to the preparation of a technical monograph on the control of health hazards from arsenic in drinking-water. This work commenced in March 1998. These decisions culminated in a joint endeavour of interested United Nations agencies including UNICEF, WHO and World Bank. It was agreed that the report would have global coverage considering the fact that arsenic in drinking water is a problem in many parts of the world. However, the current arsenic-related problems and their solutions in Bangladesh and West Bengal, India are to be highlighted.

A UN Synthesis Report on Arsenic in Drinking Water is being prepared, covering the following areas:

- Sources of Contamination
- Environmental Health and Human Exposure Assessment
- Exposure and Health Effects
- Diagnosis and Treatment of Chronic Arsenic Poisoning

- Drinking Water Quality Guidelines and Standards
- Safe Water Technology
- Communication for Development
- Development of Mitigation Strategies

This report will be a synthesis of the "state-of-the-art" arsenic knowledge. It is expected that planners, government officials, development aid agencies, and other stakeholders at the national and regional levels, as well as the scientific community in general, will use the report as a primer on arsenic and will promote necessary action. At the same time, the report will identify current knowledge gaps and research needs. The draft in preparation will be made available for public review and comment. The final draft report will be available on the WHO website at “www.who.int/water_sanitation_health/water_quality/arsenic.htm” in January 2001. Hard copy of this pre-print version will also be available for local review by January 25, 2001 in Bangladesh only.

Under the International Programme on Chemical Safety (IPCS), WHO, in conjunction with the ILO and UNEP, will publish an update of the Environmental Health Criteria for Arsenic in December 2000. The EHC provides an authoritative reference on environmental transport and distribution of arsenic; environmental levels and human exposure; kinetics and metabolism; and effects on laboratory animals and in vitro systems, on human health and on other organisms in the environment.

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Water, Sanitation & Health Program
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Fax: 41 22 791 4159, E-mail:
bartramj@who.ch

3.28 NGO Forum for Drinking Water and Sanitation

NGO Forum is an apex service delivery agency of the implementing NGOs and CBOs within the WatSan sector.

NGO Forum has established an “**Arsenic Cell**” to focus and prioritise its involvement in arsenic mitigation activities. To date NGO Forum has field-tested 20,056 water samples. Of this total number of samples 4612 were found to be above 50ppb arsenic concentrations. The tests were conducted in 2882 villages in 257 thanas of 58 districts. This data is given, on a regular basis, to the National Arsenic Mitigation Information Centre (NAMIC).

The ultimate goal of the Arsenic Cell is to provide safe drinking water for people in the intervention areas through:

I. Exploring possibilities of applicable and sustainable arsenic removal measures as well as seeking alternative water supply sources.
II. Implementation of arsenic mitigating activities for safe water supplies through NGOs & CBOs.
III. Setting up a decentralised organisational structure capable of implementing operating, and maintaining the mitigation measures.

The above mentioned objectives will be attained by:

I. Networking and collaboration with the NGOs, CBOs, government & external support agencies, multilateral organisations, researchers and academics working on this issue.
II. Optimal utilisation of NGO Forum’s resources - both software & hardware - in implementing arsenic mitigation measures.

NGO Forum is plays a role in the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP, see section 3.1.1) as a member of the steering committee as well as in the selection of Partner NGOs and CBOs for implementation in the BAMWSP project area.

To assist the promotion of easily understandable, appropriate and reliable information dissemination to communities, field and office workers involved in and affected by arsenic a partnership between NGO Forum and WaterAid Bangladesh (section 3.20) has been formed. The NGO Arsenic Information and Technical Support Unit (NAISU) will commence early 2001.

The target information group is an important aspect of the approach as the aim is to ensure understanding of the cause, effect and mitigation measures of arsenic in groundwater. The target group would include communities and field workers. These target groups require different levels of information presented in an appropriate format. In order to reach the broadest possible network the NGO Forum regional offices will have access to information via email, telephone and the postal service.

NAISU's immediate objectives are to reach out and support small to medium sized NGOs across Bangladesh who are trying to understand the issues around arsenic contamination of water supplies and support them to assist their beneficiaries to address and tackle these issues. NAISU will develop and disseminate layman's (easily understood) Bangla and English language material and training to a target population of non-technical community and field workers.

NGO Forum has developed and produced two posters and two leaflets for arsenic education. These materials have been distributed among the affected community through partner NGOs & CBOs of NGO Forum and also among other stakeholders including mass media and NAMIC.

NGO Forum has been disseminating research-oriented information relating to arsenic and arsenicosis through its monthly Bangla newsletter titled "PANIPRABAHO" and quarterly English newsletter "WATSAN". These newsletters are distributed among various NGOs, government offices and other concerned stakeholders all over the country. NGO Forum provides training on technical and social issues of arsenic mitigation.

NGO Forum is providing alternate water options which include the DPHE/DANIDA Bucket Treatment Unit (BTU), Rainwater Harvesting Systems (RWHS), Pond Sand Filters (PSF), Dug Wells and Iron & Arsenic Removal Plants (IARP).

NGO Forum has established a water quality-testing laboratory with Danida funding. The laboratory was developed with technical assistance from the School of Environmental Studies (SOES), Jadavpur University, Calcutta, India. The following water quality parameters can be tested: Arsenic, Iron, Residual Chlorine, Chloride, Fluoride, Nitrite, Nitrate, Phosphate, Sulphate, Aluminium, pH, total dissolved solids, suspended solids, alkalinity, total hardness, salinity, conductivity, turbidity, Sodium, Potassium, Calcium, COD, BOD, dissolved oxygen and bacteriological analysis.

The research activities of NGO Forum are listed in Annex 4.

NGO Forum in collaboration with DCHT, Village Education Resource Centre and WaterAid Bangladesh have undertaken small scale arsenic action research into the effectiveness of community mobilisation and information systems.

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E-mail: ngof@bangla.net

Contact: Dr Milton, Head of Arsenic Cell
4/6 , Block-E, Lalmatia, Dhaka1207
Tel- 8119597, 8119599 Fax # 8117924
E-mail: arsenic@bttb.net.bd

3.29 International Center for Diahorreal Disease Research, Bangladesh (ICDDRB)

ICDDR,B is running a health and demographic surveillance system in 142 villages of the Matlab upazilla, encompassing a 220,000 population. The Matlab health and demographic surveillance system (HDSS) was initiated in 1966. The database records all vital events and health information upgraded on a monthly basis. The data bases include child health, maternal health and nutrition information, and are linked to a GIS (Geographic Information System) database.

ICDDRB has been involved in small-scale research on arsenic exposure and mitigation. A pilot study was performed in Matlab with a sample of tube wells from all areas. In Matlab surveillance systems revealing more than three quarters of samples had total arsenic above the Bangladesh permissible limit of 50 ppb. ICDDR,B are currently (2000-2001) initiating large-scale epidemiological studies on arsenic and health consequences; Studies on arsenic exposure, the health consequences, the role of nutritional status, and effects of interventions. The laboratory capacity is currently also strengthened to serve the needs of arsenic research.

ICDDR,B has been working through local and international NGOs on arsenic monitoring and mitigation efforts which have included testing household level arsenic removal technologies, pond sand filter testing and piloting low cost rainwater harvesting techniques.

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Arsenic and Environmental Epidemiologist,
ICDDR,B, GPO Box 128, Dhaka-1212
Tel: 880-2-8811751-60 (ext 2236), 9885155
Fax: 880-2-8826050
Email: mahfuzar@icddrb.org

3.30 London School of Hygiene and Tropical Medicine (LSHTM)

LSHTM is involved in the epidemiological aspects of research on arsenicosis and arsenic mitigation efforts in various countries including Bangladesh. LSHTM have emphasised the enormity of the problem, emphasise the need to look at all aspects of safe water and for meticulous research in order to better understand the difference between dose response in various areas, health-related behaviours and sustainability of mitigation efforts.

LSHTM will provide technical support to a DFID funded Arsenic Mitigation and Epidemiology Project implemented by DCHT (see section 3.16). The main components of the project will focus on the development and assessment of community based arsenic mitigation models using epidemiological and social scientific methods. The purpose of the project is to develop a sustainable, integrated mitigation model for preventing arsenic related ill-health in Bangladesh. In addition the project will add to epidemiological knowledge of prevalence and dose response of arsenic poisoning in Bangladesh.

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Environmental Epidemiology Unit, Dept of Public Health & Policy
LSHTM, Keppel St, London WC1E 7HT, UK
Tel: 44-(0)171-9272429
Fax: 44-(0)171-5804524
Email: t.fletcher@lshtm.ac.uk

3.31 Bangladesh Consultants Limited (BCL)

A BCL team is conducting a three-month (October - December 2000) study to evaluate the disposal method of arsenic residuals related with treatment systems developed and operated in the field.

The research team will conduct a survey of selected NGOs, donor agencies, and private companies that have installed treatment units in the field. Field visits will be arranged to the installations in the villages. During the field visits, the research team will determine whether the users of the treatment units are following safe disposal methods. A record will be kept of the disposal methods observed. In addition some samples of arsenic residuals will be collected for analysis during these field trials. The samples collected will most often be taken from the soil/sludge pile on which the residuals are disposed of, although this may vary depending on the different technologies and disposal methods.

A leaching test will be conducted on the samples to determine whether the arsenic ions are bound to the solids, or propagate the arsenic contamination to the surrounding soil, surface water, and potentially, the groundwater. The BUET Environmental Laboratory will be hired to conduct the leaching tests

The output of this study will take the form of a report describing both the treatment units and the disposal methods observed in the field. It is hoped that the findings will determine whether the present operational treatment units, or more specifically the sludge disposal methods associated with these units, need to be re-evaluated.

The research report will be shared with all interested parties. The research team will present the report to all organisations that co-operated with the study and will be available for discussion should the organisation want clarification of the findings.

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4.0 Instrumentation Methods for Detection of Arsenic

The amount of testing required and the need to provide feedback to those using well water, suggest use of field testing kits. Several kits exist, but are not as yet independently validated within Bangladesh. Measuring arsenic in water accurately is not simple at concentrations important for human health. Reliable field methods are yet to be fully developed and evaluated.

Every round of water quality tests show more wells that exceed the Bangladesh standard of 50 parts per billion (ppb) for arsenic in drinking water. The equivalent of ppb is micrograms/litre or ìg/l. The World Health Organisation (WHO) guideline value for arsenic in drinking water is 10ppb.

Weaknesses of field testing include the issues such as:

(1) the field test kits being subject to fluctuations in sensitivity and accuracy depending on the model of the kit;
(2) excess light and foreign matter encountered in the field, are thought to interfere with the analysis,
(3) individual differences are inevitable when many field workers are involved (i.e. operator error).

Laboratory analysis, providing suitable quality assurance measures are introduced, will ensure the accuracy of data but is more costly than field-testing. Laboratory testing has a cost of approximately US$8 to US$10 per sample. Field-testing has a cost of approximately US$0.5 per sample.

Due to the nature of laboratory testing being remote good co-ordination is necessary with the field to ensure correct tubewells are marked with correct concentrations (i.e. painted red or green). Collaboration with field staff as well as map information and efficient transportation are essential.

Field test kits that are commercially available use the mercury bromide method or the Silver Diphenyl Dithio Carbamate (SDDC) method. Laboratory analytical equipment used includes atomic absorption spectrometry (AAS), ICP (Inductively Coupled Plasma) and ICP/MS (Inductively Coupled Plasma/Mass Spectrometry).

WaterAid Bangladesh support and advocate the local manufacture of field test kits through field user feedback to local manufacturers and discussions with interested parties.

4.1 Field Test Kit Methodologies

4.11 Mercury Bromide stain method

Most of the current field-test kits (e.g. Merck, Asian Arsenic Network -AAN, General Pharmaceuticals Limited -GPL, NIPSOM, HACH) are based on the "Gutzeit" method. This involves the reduction of arsenite and arsenate by zinc to give arsine gas which is then used to produce a stain on mercuric bromide paper.

There have been many studies on the sensitivity and reliability of these kits. The most extensively field tested of these kits are the Merck, AAN and GPL kits. The evaluations have generally shown these kits to be reasonable at detecting high concentrations (greater than 100ppb) but less reliable at lower concentrations.

The newly developed HACH kit is currently undergoing extensive field-testing and to date has produced encouraging results on both reliability and accuracy when cross-checked with laboratory testing.

The PeCo75 is a handheld instrument developed by Professor Walter Kosmus of the Karl Franzens University in Austria. This field kit is a development of the standard Gutzeit method in that it replaces zinc with sodium borohydride and so removes the problem of obtaining low-arsenic zinc. This method uses tablets instead of powdered or liquid chemicals and has a simple robust arsine generator. The PeCo75 uses a calculator-style device to measure the stain developed photometrically rather than by eye and is easily calibrated. The PeCo75 has shown good reliability and accuracy to 5ppb in laboratory environments. Field-testing is currently underway.

4.12 Calorimetric methods

Other field test kits use the SDDC (Silver Diphenyl Dithio Carbamate) method which relies on arsine generation and the colour reaction with SDDC. Arsenic hydride is absorbed into a solution of silver diphenyl dithio carbamate; the orange to red-violet soluble compound that is produced is analyzed by absorption spectrophotometry. The absorption line is measured to find the arsenic concentration. If no substances that obstruct the process are present then detection of arsenic concentrations to below 50ppb is feasible.

Two companies are currently developing single element low cost field spectrophotometers. The analytical range is claimed to be between 0-100ppb with analysis at 10ppb level guaranteed. Laboratory analyses are reported as accurate but have not, as yet, been made public. Field-testing will be required.

The two companies are based in India:

1) Spectrochemicals Limited
Email: madhav@spectrochemindia.com

2) National Chemical Laboratory
Pune 411 008, India
Fax: 91-20-5893761
Tel: 91-20-5893300
E mail: prs@ems.ncl.res.in

Table1: Basic data on field-test kits

Field Test kit	Capital Cost (approx. US$)	Commercially and locally available	Manufactured	Time taken per test (minutes)	Contact
E. Merck	50	Yes	Germany	30	?
GPL	45	Yes	Bangladesh	20	gepin@bdmail.net
NIPSOM	*?40*	*? No ?*	*Bangladesh*	*10*	*iftikhar@bdonline.com*
HACH	160	Yes	USA	30	worth@bangla.net
PeCo75	800	Yes	Austria	15	peters.engineering@styria.com
Spectrochemicals	?50	In the near future	India	??10	madhav@spectrochemindia.com
NCL	100	In the near future	India	??10	prs@ems.ncl.res.in

Further contact details:

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5.0 Arsenic Mitigation Options

Drinking water can be obtained from groundwater, surface water or rainwater sources. Each source has characteristics relating to quality, quantity, reliability, user acceptability and costs that will determine use. When considering sources and water supply technologies for arsenic mitigation, selection should be on the basis of avoidance or of a substantial and consistent reduction of the ingestion of arsenic. (ref..)

In assessing best alternative water options and / or arsenic removal technologies the following basic criteria should be evaluated:

- Water Quality (i.e. does the system consistently provide bacteriologically and chemically safe water?)
- Water Quantity (e.g. flow rate, access to water at peak times)
- Affordability (capital, operation & maintenance)
- Reliability
- Life expectancy (e.g. how does one know when to change filter media)
- Convenience (e.g. time & effort involved)
- Time considerations
- Gender issues (e.g. ergonomically appropriate, division of labour)
- Environmental risks (e.g. sludge disposal, excess water / drainage issues)
- Operational safety (e.g. user accidental misuse, physical and chemical safety, robustness)
- Risk substitution (e.g. introduction of bacteriological contamination)
- Logistical sustainability of system (e.g. are reagents available locally, life time of system, market base, involvement of private sector)
- User acceptability
- Necessary operation and maintenance training
- Information, Education & Communication

In Bangladesh, deep tube well sources provide safe water at relatively high costs. Shallow ring wells are cheaper, but provide a lower quality of water and also may dry up mid dry season. Rainwater is a good alternative in the monsoon, but requires excessive storage if the full dry season is to be bridged. Lesser investment in storage provides up to 250-280 days of drinking water. Surface water and ponds are contaminated with pathogens and begin drying up in the dry season. Tubewells with handpumps provide water near the house, but large numbers, up to 80-90 % in some coastal areas, exceed the Bangladesh arsenic standard of 50ppb, thus requiring arsenic removal technologies. (ref…)

5.1 Alternative Safe Water Options

Alternative safe water options can be provided at either household or community level.

The household level options include:

- accessing water by sharing safe (green) tubewells,
- using protected dug wells,
- rainwater harvesting,
- treating surface water (e.g by use of solar disinfection, SODIS, see annexe 7).

Community level alternative options include:

- Deep tube well with hand pump,
- Deep tube well with motorized pump, overhead tank and series of stand posts (below tank or distributed in the area),
- Rainwater harvesting,
- Surface water treatment through pond sand filters,
- Other surface water filters or treatment technologies,
- Disinfection systems

5.2 Arsenic Removal technologies

Household and community level arsenic removal technologies should be subjected to rigorous testing in idealised field conditions, in real household conditions, and in laboratory conditions. It is imperative that the performance of the technologies is adequate and as anticipated in the household or the community - not only in the laboratory or in supervised field conditions. They should produce an adequate quality and quantity of water even when the technology is subject to a certain degree of “misuse” such as may be caused by improper mixing, use beyond assumed safe removal capacity of a filter, shortcuts, etc. Removal technologies should be such that their presentation (sachet, pill or adsorbent layer), operation and functioning (mixing, settling), storage and abstraction, favour the adequate operation at the household and community level to ensure provision of safe water.

There are four main methods of arsenic removal:

- co-precipitation (coagulants form flocs that bind arsenic and are then filtered out)
- adsorption (arsenic adsorbed onto surface of media)
- ion-exchange (arsenic ions attracted to charged polymer resins)
- membrane filtration (selectively permeable membranes remove arsenic by filtration)

Some stakeholders have expressed doubts about the viability of household arsenic units, and suggested that community level arsenic removal units are preferable. They note the difficulties associated with persuading millions of households to use arsenic removal units, and in ensuring that they are used correctly, and the advantages of centralized operation and maintenance, including arsenic testing, by trained caretakers. They also express concern about the effect of private sector involvement, with its emphasis on commercial viability, on the poor. However, these compelling arguments ignore history. The failure of concerted efforts to provide community water supplies for all is what led to the massive growth in private handpump tubewells in the first place, and existing investments in community water treatment units, such as pond sand filters, or iron removal plants, have rarely produced safe or sustainable water supplies (reference: #####).

This listing of technologies does not indicate that they are safe technologies to use or that they consistently remove arsenic to below 50ppb. This listing should be used as an information point and organisations are encouraged to seek further detail either from organisations testing the technologies or the technology proponents. The responsibility for safe implementation lies with the respective implementing organisation.

5.2.1 Household level Arsenic Removal Technologies

The DFID funded (see section 3.8) Rapid Assessment of Household Level Arsenic Removal Technologies will comparatively evaluate the first nine of the household level technologies listed below. The results from this evaluation will be available by March 2001.

The CIDA funded (see section 3.7) Environmental Technology Verification study will validate a total of 13 household level arsenic removal technologies. *This three year programme commenced late 1999 (???).*

Household level arsenic removal technology options include the following (see Annexe 9 for further details of the technologies):

1. Passive Sedimentation
No proponent

2. DPHE / DANIDA Bucket Treatment Unit
Contact: DPHE-Danida Water Supply and Sanitation Components, Arsenic Mitigation Component, 2888, Central Road, Harinarayanpur, Maijdee Court, Noakhali. Ph. 0321 5582

3. Stevens' Institute Technology
Professor Meng, Center for Environmental Engineering, Stevens Institute of Technology, Hoboken, NJ 07030. E-mail: xmeng@stevens-tech.edu

Md. Suruzzaman, Earth Identity Project, House 13A, Road 35, Gulshan, Dhaka-1212. Tel: 8812049

4. Ardasha Fliter
Mr. Sounir Mojumdar, CRS-Ardasha Filter Industries, Chagalnaya Bazar, Chagalnaya, Feni

5. GARNET home-made filter
Shah Monirul Kabir, Programme Officer/GARNET Secretary, GARNET-SA, 1/7, Block-E, Lalmatia, Dhaka-1207, Tel: 9117421

6. SONO- 3 kolshi method
Professor A.H. Khan, Department of Chemistry, University of Dhaka, Dhaka-1000, E-mail: ahkhan@du.bangla.net
Dr. A.K.M. Munir, Director, SDC-Environment Initiative, College More, Courtpara, Kushtia 7000

7. BUET Activated Aluminium Filter
Dr. M.A. Jalil, Department of Civil Engineering, BUET, E:mail: majalil@buet.edu

8. Alkan Activated Aluminium Filter
M. Saber Afzal, MAGC Technologies Ltd, House 15, Road 5' Dhanmondi, Dhaka-1205. E-mail: mendota@bdmail.net

9. Tetra Hedron
US: Waqi Alam, TETRAHEDRON@prodigy.net Bangladesh: Mr. Wazir Alam or Mr. Altaf, Dhaka Tel: 9882770

10. Ion exchange resins
Contact: #####

11. **Rajshahi University / New Zealand iron hydroxide slurry**
Contact: ######

12. **SORAS (Solar Oxidation and Removal of Arsenic)**
Contact: Martin Wegelin, Daniel Gechter and Stefan Hug,
Swiss Federal Institute for Env. Science and Technology (EAWAG), Dept. of Water & Sanitation in Developing Countries (SANDEC), 8600 Duebendorf, Switzerland
internet: www.eawag.ch, www.sandec.ch
Abdullah Mahmud and Abdul Motaleb,
Swiss Agency for Development and Cooperation (SDC), GPO Box 928, Dhaka, Bangladesh

5.2.2 Community Level Arsenic Removal Technologies

Community level arsenic removal technology options include the following (see Annexe 10 for further details on the technologies):

1. Arsenic / Iron Removal Plants
18 District Towns Project, ###
Rotary International / UNICEF,
DPHE / DANIDA,
NGO Forum for safe drinking water and sanitation.

2 SIDCO
Mir Moaidul Huq, General Manager, Sidko Limited
Paragon House (7th Floor), 5, Mohakhali c/A., Dhaka-1212
Phone: 880-2-9881794 / 8827122
Fax: 880-2-9883400
E-Mail: sidko@global-bd.net

3 Alkan
M. Saber Afzal, MAGC Technologies Ltd, House 15, Road 5' Dhanmondi, Dhaka-1205. E-mail: mendota@bdmail.net

4 Arsen-X System
Contact: Ostertech Inc. 37 North Forge Drive, Phoenixville, Pennsylvania 19460, USA
Phone / fax: +610 935 066
Email: lewo@att.net

5 Tetra Hedron
US: Waqi Alam, TETRAHEDRON@prodigy.net, Bangladesh: Mr. Wazir Alam or Mr. Altaf, Dhaka Tel: 9882770

6 **?READ-F #######**

6.0 Conclusion and way forward

The conclusion and way forward is separated into an emergency or short-term strategy and a long-term strategy. The long-term strategy section is further divided into urgent issues and those that are essential but not as urgent. It is imperative that two distinct yet systematic strategies are developed to enable full co-ordination and guidance to organisations active in arsenic mitigation. The strategies should run in parallel with each other and ensure formal lesson learning and dissemination of documentation between the different and complimentary approaches. A clear distinction can be made between a strategic long-term aim and an emergency mitigation programme.

6.1 Emergency or Short Term Strategy

A rapid response is essential to provide a level of relief to arsenic effected communities and to give clear direction and co-ordination to implementers and donors a like. An emergency response should be measured in days not years.

On-going mitigation projects presently cover only limited geographical areas. Immediate action is required to create a holding situation and offer relief to families that are not yet covered by mitigation projects. The emergency response is about providing a better option not necessarily the ideal solution. It is about risk minimisation using the knowledge available today.

The emergency strategy would focus on the current level of knowledge and assisting in the immediate mitigation measures to bring relief to the worst effected areas currently identified. The emergency strategy could take a similar approach to that documented by the Emergency Arsenic Task Force (see Annexe 8). The informal Emergency Task Force was formed at the request of the Donor Local Consultative sub-group on water and sanitation and funded the development of the maps in Annexe 3.

An emergency situation requires an emergency response - fast, effective, well targeted action.

Three main areas for rapid response are:

1) Grassroots and mass media campaigns to increase awareness on arsenic avoidance and best mitigation practices (in part being carried out by BAMWSP, DPHE, UNICEF, DANIDA and other actors but there is a need for clear, simple and consistent information to avoid confusion and / or panic within the community)
2) To increase the number of people with access to safe water especially in hotspot villages (defined as villages with greater than 70% tubewells arsenic affected and at least one patient identified) and other highly effected areas. This would be done by the use of the Emergency Arsenic Task Force approach (Annexe 8) and maps (Annexe 3). Decisions on the safe water option should take into account the options listed in Annexe 8, the preliminary results from the DFID rapid assessment of household level arsenic removal technologies and the community preference. This approach would also find all arsenic 'hot spots' in the remaining districts using random survey, awareness campaigns, medics etc.
3) To increase the number of people with access to appropriate medical advice and treatment through an emergency programme similar to that documented in Annexe 8.

6.2 Long term strategy

The development of a longer-term strategy is currently hindered by key gaps in information. This section lists areas of work identified as significantly delaying progress towards a sustainable strategy of nation-wide arsenic mitigation. It is noted that formal learning from the Emergency / Short term Strategy should feed into the longer term approach but that the Emergency Strategy should not be delayed through attempting compliance with the long term strategy, e.g. awaiting results from longer term work before rapid implementation, this will defeat the objective of rapid response to people worst affected.

The following recommendations are listed under Urgent Requirements and Essential Requirements. The Urgent Requirements are seen as those areas of work, which, if undertaken, would have a wide reaching and rapid positive effect on arsenic mitigation. If funding for the Urgent Requirements were forthcoming these could be completed by appropriate organisations to give preliminary guidance within a six-month timeframe. This is realistic for the workload involved in each study but not necessarily for the administration of the funding organisation.

The Essential Requirements are issues that are not as urgent and not feasible for completion over a short time frame. A number of the Urgent Requirements will be built upon and developed further within the longer timeframe of the Essential Requirements. An example of this are the strong linkages and ongoing lesson learning between the DFID funded Rapid Assessment of Household Level Arsenic Removal Technologies and the longer term CIDA funded Environmental Technology Verification for Arsenic Mitigation (ETV-AM) work. The former is a six-month study to give preliminary results on the technical and social aspects of nine arsenic removal technologies, this information will give technology guidance to organisations that are currently implementing in the field situation and is a rapid response. The DFID work will also pre-test parts of the draft ETV-AM and the results will feed into the development of the ETV-AM. The longer term CIDA ETV-AM initiative will work over a three-year timeframe to develop a protocol for the verification of arsenic removal technologies.

Good co-ordination and communication are key to effective learning and reduction of duplicated efforts.

The recommendations do not deal specifically with apportioning responsibility for the recommended work nor do they deal with the need for organisational restructuring or institutional capacity building. It is hoped that the recommendations will be taken forward by responsible organisations that have the dynamism to react within an appropriate timeframe.

6.2.1 Urgent requirements:

The following activities and outputs should be forth coming within a six-month timeframe.

6.2.1.1 Formation of a clear, concise arsenic avoidance strategy and best practice packages.

Collation of experience on the best practices brought together in simple packages of best approach with information known to date. The starting point would be concept papers on the activities and outputs of key organisations active in particular aspects of arsenic mitigation. These would be formulated through discussion with NGOs, International NGOs, donors, Government, private sector and development banks.

The best practice packages would be separated into:

1) Information, Education and Communication Materials
2) Tubewell Screening, Monitoring, Georeferencing and Associated Protocol Development
3) Patient Screening, Treatment and Protocol Development
4) Arsenic Removal Technologies
5) Alternative Safe Water Sources
6) Data Collection, Storage, Collation and Dissemination

The best approach packages would be dynamic documentation and updated on a six monthly basis. The concept papers would act as the foundation for co-ordination and formation of working groups on key mitigation issues. The best practice packages would be formulated through participatory workshops which would involve key stakeholder organisations currently involved in arsenic mitigation programmes. The workshops would be an open forum for lesson learning, information sharing and discussion of best practices which would be documented by an independent body. The working groups specific to an aspect of arsenic mitigation would appoint a chairperson and meet quarterly to encourage co-ordination in the development of best practice approaches.

The chairs would meet on a six monthly basis, brief each other on the developments within each of the mitigation activities and encourage consistency of approach. The chair of this co-ordination meeting would be well informed to be a dynamic leader for the national co-ordination of arsenic mitigation (see section 6.2.2.1).

6.2.1.2 Field Test Kit Validation

Reliable field test kits are a prerequisite for measuring all or most of the wells in Bangladesh for arsenic. There have been at least four evaluations of arsenic field test kits within the period November 1998 to November 2000. The arsenic field test kits under development or currently available include MERCK, GPL, HACH, NIPSOM, PeCo75, NCL and Spectrochemicals (see section 4.1). The evaluations to date have focused on the accuracy and reliability of three or four of the kits. A rapid comparative assessment of the field test kits in various water chemistry parameters is essential, this will in part be addressed by a DFID funded study (see section 3.8). The evaluation would be undertaken by an objective organisation and would include intensive laboratory analysis, field testing, field user/operator feedback, assessment of reagents and methodology, assessment of manufacturers' capacity on issues such as quality assurance and production capacity. Where appropriate the evaluation would make recommendations for modifications of the kits and technical assistance would be provided to locally and regionally manufactured kits.

6.2.1.3 Technical assistance to local manufacturers

Local private sector should be encouraged to assist in the arsenic mitigation effort. Two key areas for private sector involvement are in the local manufacture of arsenic field test kits and the manufacture of arsenic removal technologies. Section 6.2.1.2 refers to the necessity for field test kits and the recommendation for technical assistance for local manufacturers.

A similar case can be made for the involvement of local private sector in the development and supply of arsenic removal technologies. It is imperative that a reliable supply chain exists for both field test kits and arsenic removal technologies. The Delhi based Regional Water and Sanitation Programme have funded a study into the supply chains of household level arsenic removal technologies. The report is currently at draft stage.

The demand for both arsenic removal technologies and field test kits exists yet local private sector is not investing readily. An encouraging environment to local private sector investment would include small to medium sized tenders, weighted scoring on tenders for local manufacture, direct technical assistance to promising developments, a transparent evaluation with constructive recommendations for technology / process modifications and ways to address broader constraints on private sector investment.

6.2.1.4 Georeferencing and labelling / tagging

The large effort required to test all tubewells within a short time frame is made more significant by the potential for data loss and duplication of testing. To minimise this risk and maximise the speed at which tubewells can be tested, data recorded and monitoring systems put in place the issue of georeferencing and tagging or labelling of tubewells must be addressed.

Currently the protocol is for tubewells to be painted red or green depending on their unsafe or safe status. BAMWSP request that the tubewell testing information is then forwarded to the National Arsenic Mitigation Information Centre (NAMIC). The majority of organisations do not georeference the tubewells and the information received by NAMIC may be referenced by village, upazilla or name of tubewell owner. This variety of data is difficult to store in an accessible form.

A strategy or protocol for the use (and availability) of Geographical Positioning Systems (GPS) in the collection of tubewell testing data needs to be formulated. ACIC (see section 3.15) have suggested a pool of GPSs available for organisations without immediate access to GPSs. A GPS currently retails at approximately US$150.

The long-term sustainability of painting tubewells red or green should be revisited. Paint peels or fades and can be painted over. As an emergency measure the red / green paint is a solution but on a longer-term basis a more complete data set would be useful at the tubewell. Each tubewell would be georeferenced and data recorded in an easily accessible format by a central body (e.g. NAMIC) but at community level a system of tagging or labelling with important data is required. The data marked on each tubewell would include the arsenic concentration, the date of testing, the test kit used and the organisation responsible for the test. This information would be easily available to the household and other organisations carrying out tubewell screening.

The NAMIC data recording format must be systemised and widely distributed if the data that NAMIC request is to be of use to the arsenic mitigation effort. The tubewell tagging or labelling mechanism must also be standardised.

6.2.1.5 Guidance on cost recovery / subsidies

A consistent, realistic strategy for cost recovery on provision of safe water (either through alternative sources or arsenic removal mechanisms) and arsenic field testing costs. A projection of necessary budget for initial testing and regular monitoring of water quality using field and laboratory methodologies is necessary as is a budget projection of provision of safe water to all effected households.

Policy should be formulated through discussion with stakeholders including NGOs, Government, donors, development banks, private sector and community leaders. A top down approach is unlikely to be successful.

6.2.1.6 Rapid assessment / evaluation of alternative water source options

A large number of organisations have experience in alternative water source technologies. These technologies include household and community level technologies (see section 5.1). The collation of the available data would enable a simple decision tree to be formulated to assist in alternative source selection at field level. *Note:* A more substantial, longer-term study could be undertaken which would feed into Essential not Urgent Requirements.

6.2.1.7 Food chain and health effect studies

The human health significance of other sources of arsenic, such as those via the food chain, need to be further explored, as do the relationships between diet/nutrition and the long-term effects of arsenic, and the dose-response and dose-effect relationships in drinking water.

Knowledge on health effects of arsenic is incomplete and the situation is complicated by factors such as Hepatitis B, nutritional status and the actual form of arsenic.

DCHT (see section 3.16) are commencing a three-year programme to answer some of these questions. A rapid collation of existing data, including information from DCHT, would be a useful exercise to support dietary advice to arsenicosis patients.

6.2.1.8 Information dissemination strategy

The poor availability of reliable information hinders action at all levels and may lead to panic, exacerbated if misleading reports are made. Effective information channels have yet to be established to those affected and concerned.

All recommendations made within this report are void if effective, accurate and rapid communication and information dissemination does not take place. A clear strategy, taking into account the different target groups and level of information required, is an essential part of an arsenic mitigation effort.

Ease of access to information is essential and organisations should be encouraged to share information widely. The central body of NAMIC has responsibility for information collection, collation and dissemination. The volume of data and documentation is large. The capacity of NAMIC or any one organisation for this task should be assessed.

Dissemination channels should include mass awareness and community awareness in addition to the dissemination of technical reports or strategies. Different media have different target audiences. Information channels should include radio, television, newspapers, IEC materials, internet, newsletters, workshops, etc.

A reference listing of available reports on particular aspects of arsenic mitigation should be made available and a central resource centre for arsenic documentation and materials set up. The resource centre would hold easily accessible documentation and be staffed by resource personnel able to assist in recommending reports and giving advice or referral for appropriate technical advice. The resource centre would respond to email and telephone queries and requests for information. NGO Forum for drinking water and sanitation and WaterAid Bangladesh (see section 3.20) are currently setting up this type of a resource centre for small to medium sized NGOs.

6.2.2 Essential requirements:

The following activities and outputs will lead on from the previous section 6.2.1.

6.2.2.1 Formation of a Rapid Response Committee

The need to identify knowledge gaps and initiate appropriate work to bridge these gaps will be a continuous process. Section 6.2.1.1 outlines the need for best practice packages and working groups to take forward particular initiatives. The meeting of the chairs of these working groups would be a forum for identification of knowledge gaps. The group or committee would have strong linkages with key organisations active in arsenic mitigation. The chair of this co-ordination meeting would be well informed to be a dynamic leader for the national co-ordination of arsenic mitigation.

The chair of each working group must give appropriate time and importance to the identification of knowledge gaps. The six monthly meeting of working group chairs would then recommend initiating particular works. This group or committee would have an easily accessible budget donated by various donors and would have the ability to engage consultants for short-term studies to stopper knowledge gaps. For effective outputs from this initiative a system of either remuneration or chair rotation should be in place to ensure an unrealistic workload is not placed on the chairs. Clearly the accountability, transparency and terms of reference for such a committee need to be fully addressed and documented. It would be useful to have diverse membership of the committee including representatives from research, donor, Government, NGO and private sector organisations. Ideally Government would chair such a committee.

6.2.2.2 Co-ordination

Leading from section 6.2.1.8 and 6.2.2.1 clearer information dissemination and co-ordination of the many different arsenic mitigation initiatives is essential in the effective coverage and timely assistance to communities.

The Emergency Arsenic Task Force maps (Annexe 3) indicate the geographical distribution of the larger organisations' mitigation efforts. These maps give an overview of the working areas but need constant updating and further detail to be a fully utilised tool. This additional detail and data is essential and is related to the extent of the organisations' activities within a particular thana and the planned timing for implementation. For example an organisation could be working in only 2 villages within a particular thana but unless more detailed GIS maps exist it may be read as the entire thana being covered by a certain organisation. A similar problem arises with timing of interventions. If an organisation is planning to work in 30 thanas it is unlikely that the work will be simultaneous, it may be spread over a two-year period. Easy access to this information is important for co-ordination of ongoing mitigation efforts and geographical direction for new interventions.

6.2.2.3 Three month national level objectives with shared responsibility and clear timing for outputs

To encourage accountability, transparency and achieving outputs a participatory workplan exercise for arsenic mitigation should be formulated. A national level rolling three-month workplan would be widely shared with interested stakeholders. The workplan would be formulated with and by key stakeholders. The stakeholders would share the responsibility for monitoring and action on certain outputs.

Clear outputs, responsibilities, timing and funding arrangements would be documented and the overall national programme monitored against the set objectives. It would not be the sole responsibility of the largest programme to achieve each of the set objectives / outputs but to ensure responsibility for a particular output was assigned to an appropriate organisation.

The work plans would move from three to six-monthly within two years.

6.2.2.4 Small contracts / tenders to encourage local private sector

On going support for local private sector participation (section 6.2.1.3) through the letting of small contracts and provision of an appropriate enabling environment.

6.2.2.5 Public, NGO, donor, private sector working together

Look for innovative ways to encourage public, private, NGO and donor organisations to work together and share information.

6.2.2.6 Tubewell Monitoring Strategy & Seasonality testing

Development of a cost effective, technically sound monitoring strategy for field testing of tubewells.

Design and implementation of a study to assess the seasonal variations of arsenic in groundwater.

6.2.2.7 Deep Aquifer Investigations

Collation of data and design of further work to assess the feasibility of the deep aquifer as a partial or full solution for arsenic mitigation. Various amounts of deep aquifer investigations have been funded by DPHE, JICA, DFID, UNICEF and DANIDA. Collation of this data and the co-ordination of new initiatives is key to the development of a deep aquifer protection and use strategy.

6.2.2.8 Health Issues

A significant amount of work is ongoing with relation to water testing, treatment and arsenic release mechanisms. Less work focuses on the health impacts and medical aspects of the problem. Clearly the water quality and medical issues are related but currently research and documentation appears to focus on the groundwater issues.

A working group similar to that proposed in section 6.2.1.1 and 6.2.2.1 could formulate a strategy identifying medical knowledge gaps. Training of health officials to recognise symptoms of arsenic poisoning and the appropriate treatment is one area useful work.

6.2.2.9 Lesson learning regionally

Other than Bangladesh countries within the region which have reported high arsenic concentrations include India, Nepal, Thailand, Vietnam, China, *Sri Lanka* and Pakistan.

The case for regional lesson learning and experience sharing is strong. Currently there is little information exchange between the affected countries. A formal mechanism for regional information exchange is necessary to ensure that good practice is rapidly propagated.

Annex 1

PRIMARY, SECONDARY AND TERTIARY SYMPTOMS OF ARSENICOSIS

Note: taken from Dhaka Community Hospital Trust Information

IN PRIMARY STAGE

1.Melanosis - Darkening or blackening of skin colour. Small black spots or diffuse black patches particularly over the trunk and back then gradually over the whole body.

2.Keratosis - Skin becomes hard & rough especially on palms of hands soles.

3.Conjunctivitis- Reddening of eyes.

4.Bronchitis- Infection of respiratory system.

5.Gastroenteritis- Includes nausea, vomiting and loose motion.

IN SECONDARY STAGE

1.Leuko-melanosis- Black & white spots on various parts of the skin of the body.

2.Hyperkeratosis- Rough nodules on palm & sole.

3.Non pitting edema- Swelling of leg.

4.Peripheral neuropathy - Terminal neurosis.

5.Kidney & liver- Various complications of kidney &liver occur.

IN TERTIARY STAGE

1.Gangrene- Necrosis with putrefaction of terminal limbs of the body.

2.Cancer- Cancer of skin, urinary bladder & lungs.

3.Failure of function of the liver.

4.Failure of function of the kidney.

Annexe 2

Dhaka University Research Papers

Department of Geology

Research Supervised/conducted by Dr. K M Ahmed, at Geology Department, DU:

M.Sc. Theses:

1. Geology and Geochemistry of Arsenic Occurrence in Groundwater of Singair Thana, Manikganj District. M.Sc. Thesis (M Shahnewaz), Department of Geology, University of Dhaka, 1999.
2. A Comparative Study of Arsenic Contaminated (Iswardi, Pabna) and Non-Contaminated (Thakurgaon Sadar) Aquifers, NW Bangladesh. M.Sc. Thesis (S Shamima Parveen), Department of Geology, University of Dhaka, 1999.
3. Physico-Chemical Status of Arsenic Contaminated Aquifers in Nawabganj Sadar and its Surroundings, Nawabganj District. M.Sc. Thesis (S M M Alam), Department of Geology, University of Dhaka, 1999.
4. Origin and distribution of arsenic in central Bangladesh. M. Sc. Thesis (Ross Nickson), Department of Geological Sciences, University College London, UK, 1997.
5. Arsenic in groundwater at Meherpur, Bangladesh-a vertical pore water profile and rock/water interactions. M. Sc. Thesis (J Perrin), Department of Geological Sciences, University College London, UK, 1998.
6. Arsenic in groundwater at Meherpur, Bangladesh-spatial variations and hydrogeological controls. M. Sc. Thesis (M Burren), Department of Geological Sciences, University College London, UK, 1998.
7. The vertical and spatial variability of arsenic in the groundwater of Chaumohani, Southesat Bangladesh. M.Sc. Thesis (S Mather), Department of Geological Sciences, University College London, UK, 1999.
8. Arsenic occurrence and distribution in Tala, Satkhira, SW Bnagladesh. M.Sc. Thesis (L Mazumder), Division of Land and Water, Royal Institute of Technology, Sweden - 1999.
9. The vertical and spatial variability of arsenic in Magura town, SW Bangladesh. M.Sc. Thesis (J Cobbing), Department of Geological Sciences, University College London, UK, 2000.
10. Arsenic in groundwater at Magura, SW Bangladesh-a vertical pore water profile and rock/water interactions. M. Sc. Thesis (A Carruthers), Department of Geological Sciences, University College London, UK, 2000.
11. Modelling of arsenic transport in Magura area, SW Bangladesh. M. Sc. Thesis (H Cheetam), Department of Geological Sciences, University College London, UK, 2000.
12. Geostatistical and Hydrogeological Evaluation of Arsenic Field Testing Data from Jhikargachha Upazila, Jessore, SW Bangladesh. M.Sc. (Sabiqunnahar) - ongoing.
13. Investigation of the Deeper Aquifer as a Source of Arsenic Free Water in Kachua Municipality, Chandpur, SE Bangladesh. M.Sc. (M Zubaer Ahmed)- ongoing.
14. Vertical profiling of arsenic in groundwater, porewater and sedimants from Magura, western Bangladesh (Alison Carruthers)
15. Modelling the movement of arsenic to public water supply wells in the deep alluvial aquifer, southern Bangladesh (Helen Cheetham)

Other Research:

1. Sedimentological and Mineralogical Studies on Arsenic Contaminated Aquifers within Bangladesh. For Ground Water Circle, Bangladesh Water Development Board. Completed December 1997.
2. Sedimentological and Mineralogical Studies on Arsenic Contaminated Aquifers within Bangladesh. For Ground Water Circle, Bangladesh Water Development Board. Completed September 1998.
3. Sedimentological and Mineralogical Studies on Arsenic Contaminated Aquifers within Bangladesh. For Ground Water Circle, Bangladesh Water Development Board. Completed September 1999.

The following papers have been prepared jointly with the Geohazard Research Group (GRG) in the Department of Geology, University of Dhaka.

Khan, A.A., Akhter, S.H. and Bhuiyan, A.H. 1999. Arsenic in groundwater vis-a-vis impact of watershed management in the Ganges delta of Bangladesh. Oriental Geographer, v.43, No. 2, p. 1-14.

Khan, A.A., Akhter, S.H, Hasan, M.A., Ahmed, K.M. and Imam, M.B. Etiology of arsenic in the groundwater of the Bengal Delta - constraints from geological evidences. KTH-DU Special Publication Volume "Groundwater Arsenic Contamination in the Bengal Delta Plains of Bangladesh", Royal Institute of Technology, Stockholm, Sweden. (Accepted).

Khan, A.A. and Akhter, S.H. Can geophysical resistivity detect arsenic contaminated aquifer? KTH-DU Special Publication Volume "Groundwater Arsenic Contamination in the Bengal Delta Plains of Bangladesh", Royal Institute of Technology, Stockholm, Sweden. (Accepted).

Ahmed, K.M., Imam, M.B., Akhter, S.H., Hasan, M.A. and Khan, A.A. Sedimentology and mineralogy of the arsenic contaminated aquifers in the Bengal Delta of Bangladesh. KTH-DU Special Publication Volume "Groundwater Arsenic Contamination in the Bengal Delta Plains of Bangladesh", Royal Institute of Technology, Stockholm, Sweden. (Accepted).

Khan, A.A., Alam, S.M.M. and Akhter, S.H. Clay and the fate of arsenic transport in the Upper Ganges Delta Plain of Bangladesh. Accepted for presentation and publication in the Proceedings of International Symposium on Suction, Swelling, Permeability and Structure of Clays. IS-Shizuoka 2001, January 11-13, 2001, Japan. A. A. Balkema Publishers, Rotterdam, Netherlands.

Khan, A.A., Akhter, S.H. and Alam, S.M.M. Evidence of Holocene transgression, dolomitization and the source of arsenic in the Bengal Delta. Proceedings of GEO2000, Int. Conf. Geotech. Geoenv. Eng. And Management. UAE University at Al Ain, 4-7 November, 2000. A. A. Balkema Publishers, Rotterdam, Netherlands.

Khan, A. A.; Imam, B.; Akhter, S. H.; Hasan, M. A. & Ahmed, K. M. U. 1998. Subsurface investigation in the arsenic problem areas of Rajarampur, Chanlai and Baragharia, Nawabganj district, Bangladesh. Research Study Report for UNICEF-DPHE.

Imam, B.; Akhter, S. H.; Khan, A. A.; Hasan, M. A. & Ahmed, K. M. 1998. Sedimentological and Mineralogical studies on aquifer sediments within Bangladesh. Research Study Report for Groundwater Circle, Bangladesh Water Development Board.

Khan, A. A.; Akhter, S. H.; Ahmed, K. M. & Hasan, M. A. 1999. Sedimentological and Mineralogical studies on arsenic contaminated aquifers within Bangladesh. Research Study Report for Ground Water Section, Bangladesh Water Development Board.

Khan, A. A. and Alam, S. M. M. Oxidation - reduction debate on arsenic vis-a-vis options for safe water. Accepted for publication in the "Bangladesh Environment 2000", a publication of the International Conference on Bangladesh Environment (ICBEN-2000), ITN, BUET.

Annexe 3

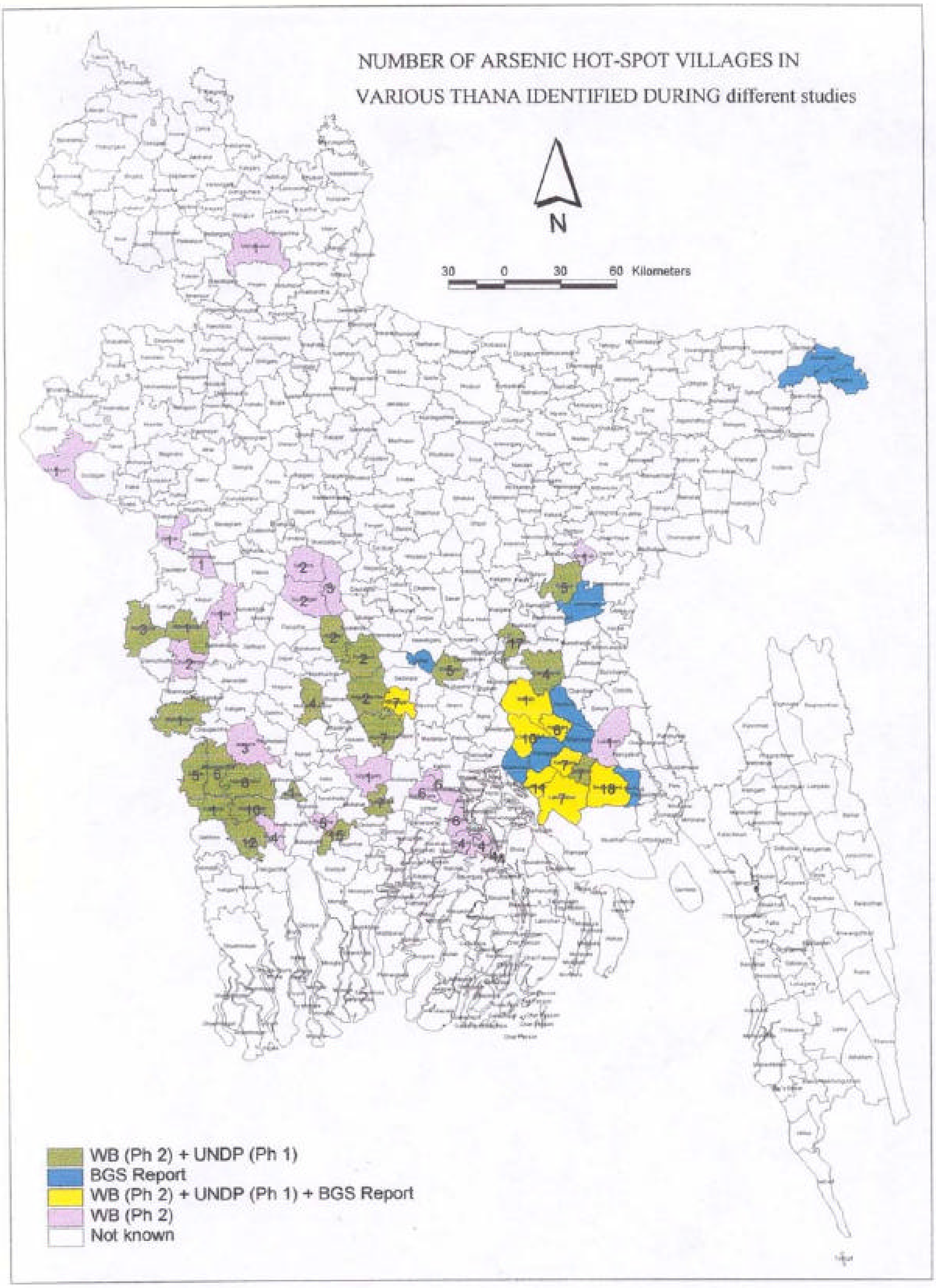
EMERGENCY ARSENIC TASK FORCE MAPS OF HOTSPOT VILLAGES

1. ***MAP 1 Number of arsenic hot-spot villages in various thanas***

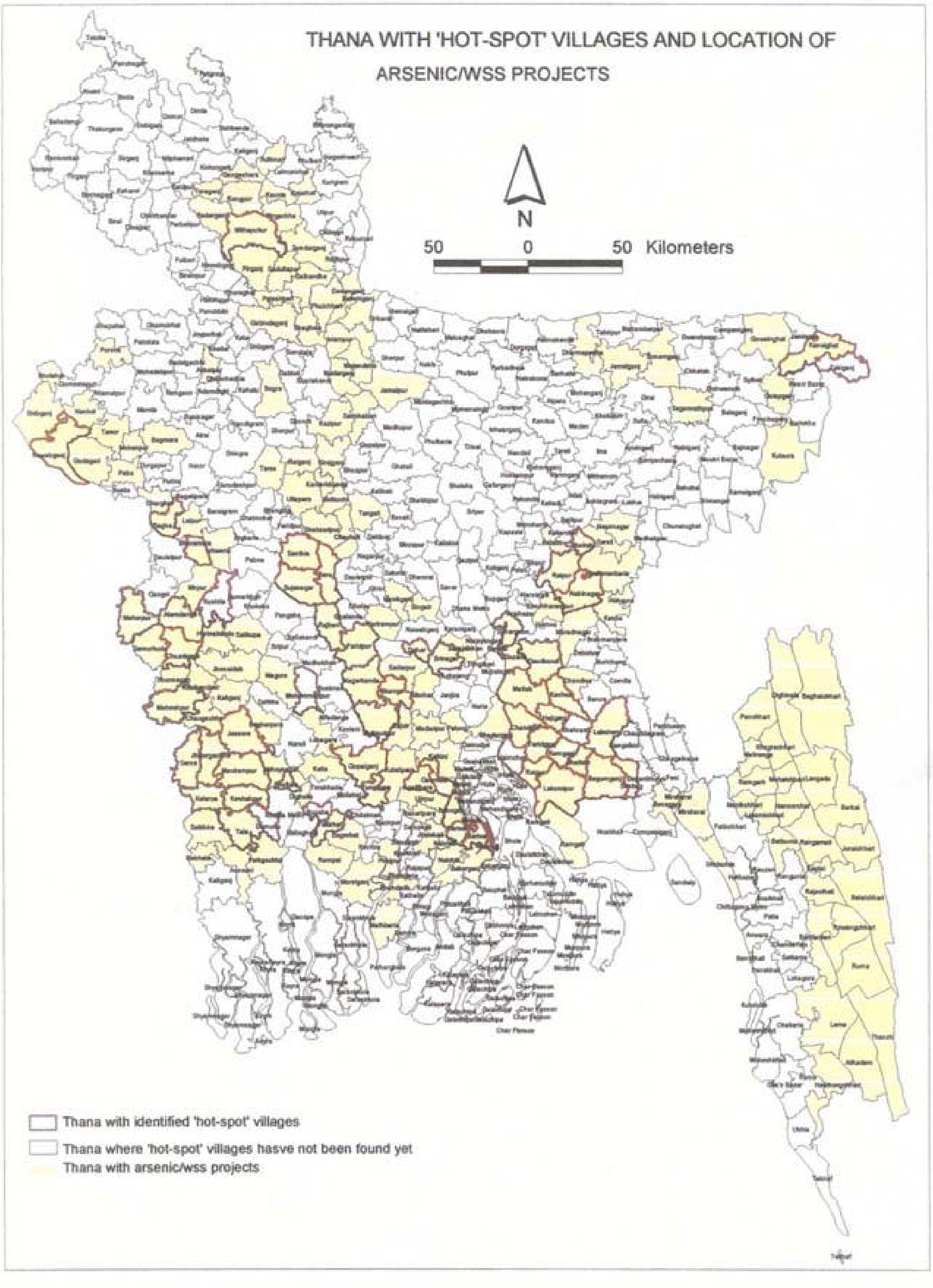
2. ***MAP 2 Thanas with hot-spot villages and location of arsenic/WSS projects***

3. ***MAP 3 Thana locations of different agencies arsenic/WSS projects***

MAP 1

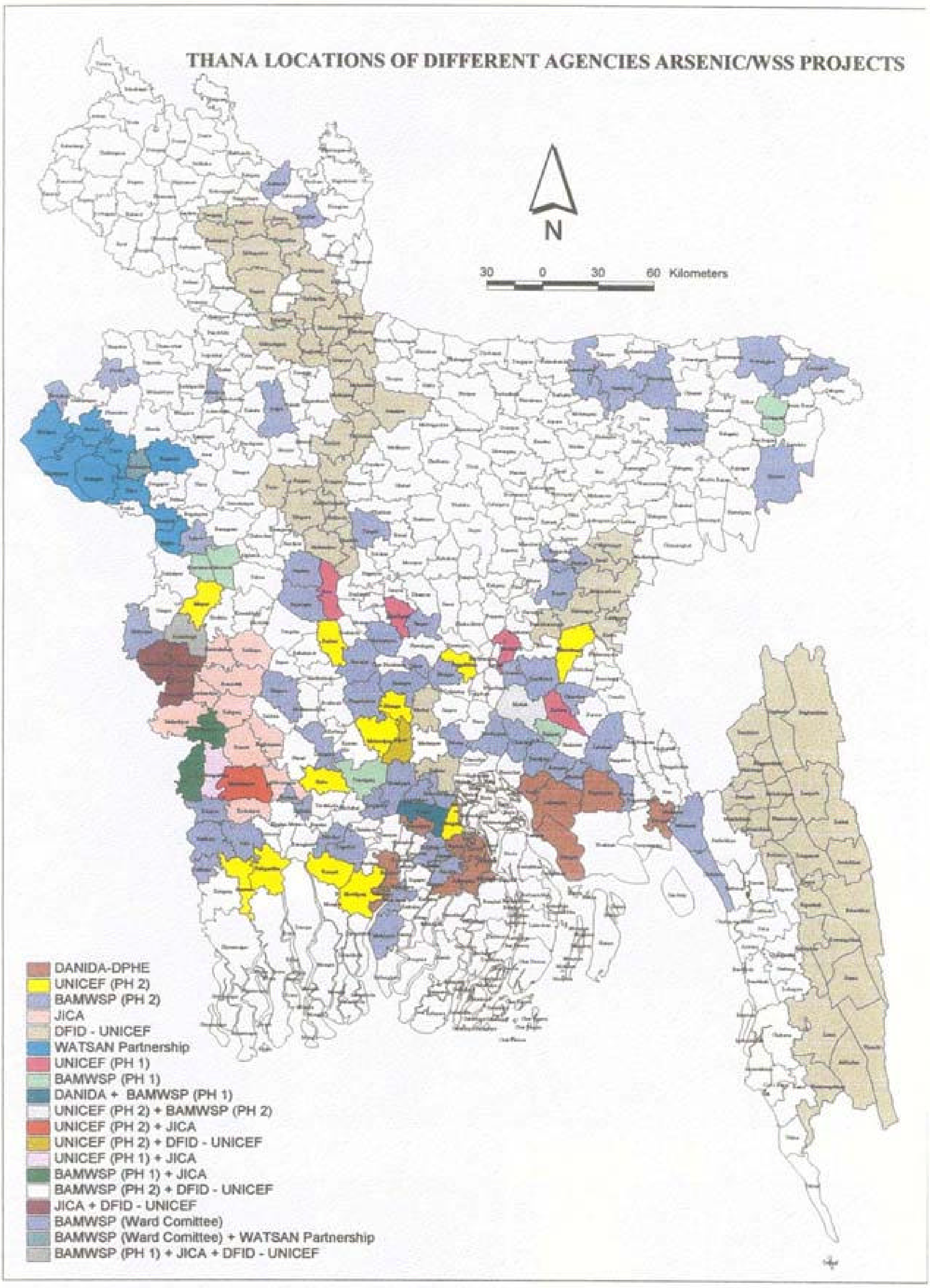

NUMBER OF ARSENIC HOT-SPOT VILLAGES IN
VARIOUS THANA IDENTIFIED DURING different studies
N
30 0 30 60 Kilometers
WB (Ph 2) + UNDP (Ph 1)
BGS Report
WB (Ph 2) + UNDP (Ph 1) + BGS Report
WB (Ph 2)
Not known

MAP 2



THANA WITH 'HOT-SPOT' VILLAGES AND LOCATION OF
ARSENIC/WSS PROJECTS
N
50
0
50 Kilometers
Thana with identified 'hot-spot' villages
Thana where 'hot-spot' villages hasve not been found yet
Thana with arsenic/wss projects

MAP 3


THANA LOCATIONS OF DIFFERENT AGENCIES ARSENIC/WSS PROJECTS
N
30 0 30 60 Kilometers
DANIDA-DPHE
UNICEF (PH 2)
BAMWSP (PH 2)
JICA
DFID - UNICEF
WATSAN Partnership
UNICEF (PH 1)
BAMWSP (PH 1)
DANIDA + BAMWSP (PH 1)
UNICEF (PH 2) + BAMWSP (PH 2)
UNICEF (PH 2) + JICA
UNICEF (PH 2) + DFID - UNICEF
UNICEF (PH 1) + JICA
BAMWSP (PH 1) + JICA
BAMWSP (PH 2) + DFID - UNICEF
JICA + DFID - UNICEF
BAMWSP (Ward Comittee)
BAMWSP (Ward Comittee) + WATSAN Partnership
BAMWSP (PH 1) + JICA + DFID - UNICEF

Annex 4

NGO Forum arsenic related research activities:

RESEARCH ACTIVITIES

- Conducted a study on evaluation of arsenic field testing kits in collaboration with School of Environmental Studies (SOES), Jadavpur University, West Bengal, India.

Ongoing Research activities

- Conducting research on different aspects of arsenic including Quality of alternative arsenic-free safe water options.

- Evaluation of BTU in terms of Social acceptability, Arsenic removal efficiency, Health hazards and cost effectiveness (Danida supported).

- Randomised Invention trial to assess dietary contribution to total arsenic exposure, (Aus Aid funded, in collaboration with NCEPH, Australian National University, Canberra)- Data collection phase is over, food & biological samples are being analysed now at Canberra).

- Health hazards (Respiratory effects, Nutritional status, Hypertension) caused due to ingestion of arsenic (NGO Forum initiative)- data completion is over and report will be published soon.

Annex 5 Water Quality Fact Sheet:

Arsenic

WHO guideline value (recommended limit): 10 μg 1-^{1}
National standard in most countries: 50 μg 1-^{1}
Typical range in groundwater: usually < 10μg 1-^{1} (up to around 3000 μg 1-^{1})

This is one of a serious of information sheets prepared for a limited number of inorganic constituents of significant health concern that are commonly found in groundwater. The sheets aim to explain the nature of the health risk, the origin and occurrence of the constituent in groundwater, the means of testing and available methods of mitigation. The purpose of the sheets is to provide guidance to WaterAid Country Office staff on targeting efforts for water-quality testing and to encourage further thinking within the organisation on water-quality issues.

Health effects

Arsenic is a ubiquitous element found in the atmosphere, soils and rocks, natural waters and organisms. It is mobilised in the environment through a combination of natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of human activities, including mining, industry and agricultural use of arsenical pesticides. Of the various sources of arsenic in the environment, drinking water probably process the greatest threat to human health.

Arsenic has long been recognised as a toxin and carcinogen. Long-term ingestion of high concentrations from drinking water can potentially give rise to a number of health problems, particularly skin disorders, of which the most common are pigmentation changes (dark/light skin sports) and keratosis (warty nodules, usually on the palms and feet). Additional symptoms include other more serious dermotalogical problems (e.g. skin cancer and Bowen's diease), cadio-vascular (blackfoot disease, Raynaud's syndrome, hupertension, gangrene), neurological, respiratory and hepatic dieases as well as diabetes mellitus. Such symptoms have been well-documented in areas of known groundwater contamination such as Bangladesh, West Bengal, Taiwan, northern China, Mexico, Chile and Argentina.

A number of internal cancers have also been linked with As in drinking water, particularly lung, bladder, liver, prostate and kidney cancer (e.g. Smith et al., 1992 - 1998). Much research is being carried out to assess the risks of such cancers at the levels of the drinking-water standards. Clinical symptoms of As poisning and their relative prevalence seem to vary between affected regions and there is no clear agreement on the definition of As poisoning.

Some studies have shown a clear relationship between arsenic dose from drinking water and the development of cancer and other diseases. However, the relationship may be complicated by other factors such as nutritional and general health status (hepatitis B may exacerbate the problems) and water chemistry (e.g. aqueous arsenic chemistry, dissolved iron concentration). Debate also remains over whether a threshold as concentration exists below which the element is effectively safe (e.g. Smith et al., 1999).

Latency periods of several years for the development of arsenic-related health problems have been noted in several investigations a factor which in part explains why many of the problems in developing countries have only recently emerged despite several years of groundwater use.

Many of the advanced and most serious clinical symptoms are incurable, others can be treated and symptoms can to into remission provided a supply of low-As drinking water is provided a relatively early stage. Early detection of arsenic in drinking water and provision of low arsenic alternatives is therefore critical and the element warrants special monitoring in potentially vulnerable groundwaters.

Following the accumulation of evidence for the chronic toxicological effects of As in drinking water, recommended and regulatory limits of many authorities are being reduced. The WHO guideline value for As in drinking water was provisionally reduced in 1993 from 50 μg 1-^{1} to 10 μg 1-^{1} The new recommended value is based largely on analytical capability. Standards based on risk alone would likely be lower still. At present, most countries, and indeed all developing countries, continue to use the 50 μg 1-^{1} limit as the national standard because of limited analytical capability.

Occurrence in groundwater

Arsenic concentrations in natural waters vary significantly, potentially spanning more than four orders of magnitude. Groundwaters are generally more vulnerable to accumulation of high arsenic concentrations than surface waters because of increased opportunity for chemical reactions between water and host rocks and the high ratios of solid to solution compared to surface waters. Exceptions can occur locally where surface waters (as well as groundwaters) are contaminated by point sources (mining, geothermal, industrial) or where river waters have a high component of baseflow (groundwater). Groundwaters are where the greatest number of, as yet unidentified, high- arsenic sources are likely to be found.

Observed arsenic concentrations in groundwater are themselves highly variable. Most groundwaters tend to have concentrations < 10 μg 1-^{1} but may range up to and in excess of 3000 μg 1-^{1} in some conditions. Arsenic and fluoride together are now recognised as the greatest problems of all inorganic constituents in groundwater.

Most cases of arsenic contamination in groundwater are naturally-derived, either due to the occurrence of favourable oxidation/ reduction and pH conditions in the aquifers (see below) or due to inputs from local geothermal sources. Arsenic problems may also be exacerbated in areas affected by mining activity (coal and metals associated with sulphide minerals). Both mining effluent and geothermal waters often have arsenic concentrations in the milligram-per-litre range and can cause major increases in concentrations of surface waters and groundwaters. Unlike affected major aquifers, these tend to be relatively localised to the contaminant source and are usually easily identified. Contam-ination from industrial sources may also be severe locally, but such cases are comparatively rare.

Unlike many other toxic trace elements, arsenic is potentially highly mobile in water given the appropriate environmental conditions. It forms anionic (negatively charged) species in water and hence unlike cations can be stable in soluble form at the neutral to alkaline pHs (6.5-8.5) characteristic of most groundwaters. However, arsenic is strongly adsorbed (adhered) onto sediments and soils, particularly iron oxides, as well as aluminium and manganese oxides and clays. These are common constituents of aquifers and are the reason why most groundwaters have low arsenic concentrations.

Arsenic occurs in two oxidation states in water . In reduced (anaerobic) conditions, it is dominated by the reduced form: arsenite and in oxidising conditions by the oxidised form: arsenate. Ad-sorption (and hence restricted mobility in water) is particularly strong for arsenate.

High arsenic concentrations in groundwater are mainly found in cases where adsorption is restricted. These are found naturally under two main types of conditions:

ii) strongly reducing (anaerobic, low-Eh) ground-waters where arsenite dominates and hence sorption to oxides is less favourable. Iron oxides themselves may also dissolve in such conditions, which may release funher arsenic;

iii) oxidising (aerobic) aquifers with high groundwater-pH values (> 8), typically restr-icted to arid or semi-arid environments. Such groundwaters commonly also have high con-centrations of other potentially toxic elements such as fluoride, boron, uranium, vanadium, nitrate and selenium.

Although the precise mechanisms of arsenic release in groundwater are not yet fully understood, there appear to be two further criteria necessary for the development of high arsenic concentrations in groundwaters from these two environments. Naturally- contaminated aquifers recognised so far tend to be:

i) geologically young (ie. sediments deposited in the last few thousand years) and;

ii) groundwaters characterised by slow flow conditions, either because of low hydraulic gradients low-lying areas such as flat alluvial basins and the lower parts of deltas) or lack of active rainfall and recharge (arid areas, closed basins).

Examples of anaerobic aquifers affected by arsenic include the alluvial and deltaic aquifers of Bangladesh and West Bengal (formed by erosion of the Himalaya in the last few thousand years), and alluvial and lake sediment aquifers of Inner Mongolia, southern Taiwan and the Danube Basin, Hungary. Examples of oxidising aquifers with arsenic problems include the loess aquifers of central Argentina and Chile (formed over the last few thousand years largely by wind erosion of Andean rocks) and alluvial aquifers of northern Mexico and parts of south-west USA (Figure 1; Smedley and Kinniburgh, 2000).

Arsenic problems in mining and mineralised areas occur because of the oxidation of sulphide minerals (especially pyrite and arsenopyrite) which can contain very high concentrations of arsenic and which oxidise by aeration, particularly by the disturbances created by the mining activities. Arsenic problems have been recorded in sulphide-mining areas in many parts of the world, but are particularly well documented in parts of Thailand, Ghana, the USA and Canada (Figure 1). Recent health problems from mining-related arsenic contamination have also been recognised in part of Madhya Pradesh, India.

Areas where potential future arsenic problems may be identified therefore include:

i) large low-lying present-day alluvial and deltaic basins composed of young sediment where groundwater flow is slow or stagnant and where anaerobic conditions prevail (poss-ibilities include the lower reaches of the Indus Valley , Pakistan, the Mekong and Red River deltas of Vietnam and possibly the lower reaches of the Niger Delta,

DOCUMENTED ARSENIC PROBLEMS IN GROUNDWATER AND THE ENVIRONMENT

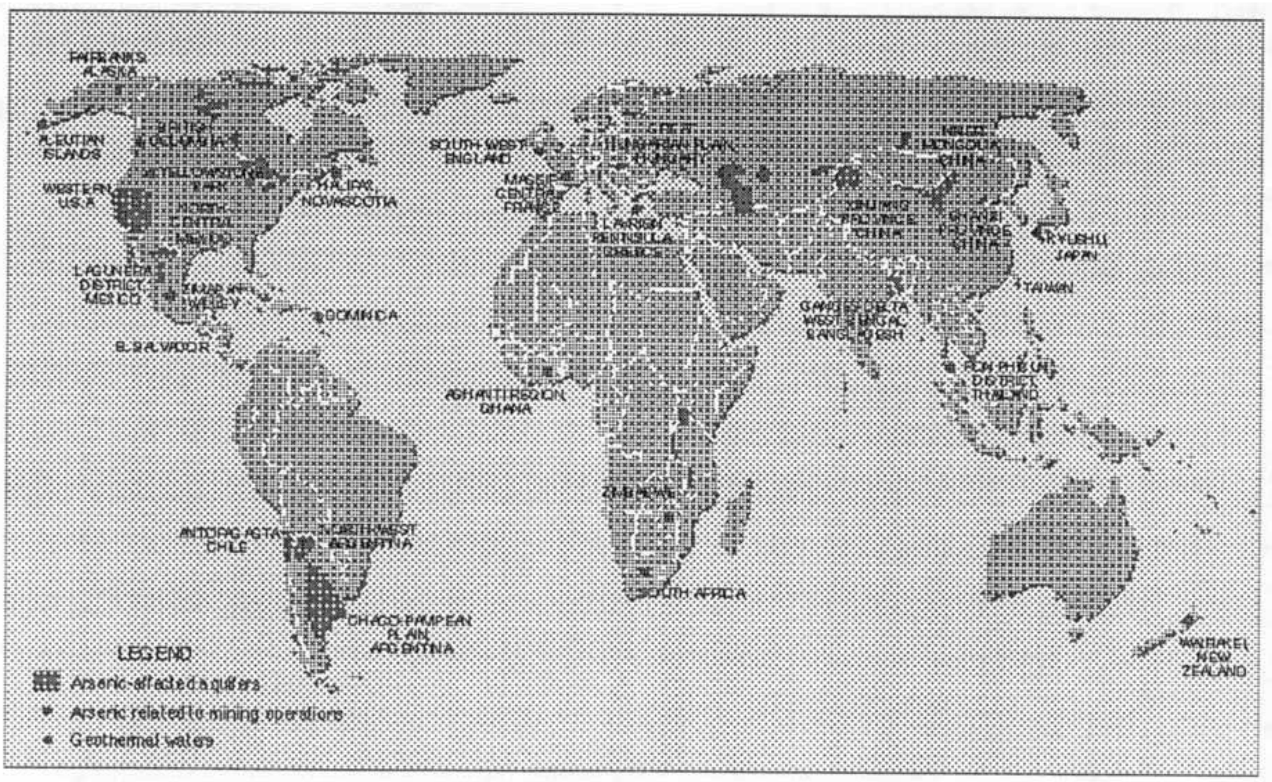


Figure 1. Documented arsenic problems in groundwater and the environment. Includes known occurrences of geothermal and mining-related arsenic problems

Nigeria);

ii) inland basins with young sediments in arid and semi-arid areas (such as parts of northern China);
iii) sulphide mining and mineralised areas (occurring in basement aquifers in for example parts of Africa, including Ghana, South Africa, Zimbabwe and India);
iv) geothermal areas (possibilities include the East African Rift of T anzania, Uganda and Kenya, although no arsenic data are known for the region).

Arsenic in water is invisible and has no taste or smell. Hence other diagnostic features of water chemistry need to be investigated to identify potential arsenic occurrences. Features of the different types of high-arsenic groundwater environ-ment are shown in Figure 2.

Field testing for arsenic

Arsenic has not been traditionally included on lists of elements routinely tested by water- quality testing laboratories in developing countries and so some arsenic-rich sources undoubtedly remain to be identified. The recent discovery of arsenic contam-ination on a large scale in Bangladesh in particular has highlighted the need for a rapid assessment of the situation in similar aquifers world-wide. The intended revision of the drinking-water standard for arsenic in a number of countries has also prompted the need for inclusion of the element in water-quality monitoring programmes.

Aquifers with identified arsenic problems typically have a high degree of spatial variability in concentrations within relatively short distances (metres to kilometres). This means that in vulnerable aquifers, ideally each well used for drinking water needs to be tested to ensure its fitness for use. In affected aquifers such as those of Bangladesh, this can mean large numbers of sources (several million tubewells). Laboratory analysis is preferable, but difficult on such a large scale. Field-test kits are an alternative, but need to be simple, rapid, inexpensive and reliable to use.

Most of the current field-test kits {e.g. Merck, Asian Arsenic Network, All-lndia Institute of Hygiene & Public Health, NIPSOM (Bangladesh)) are based on the 'Gutzeit' method,

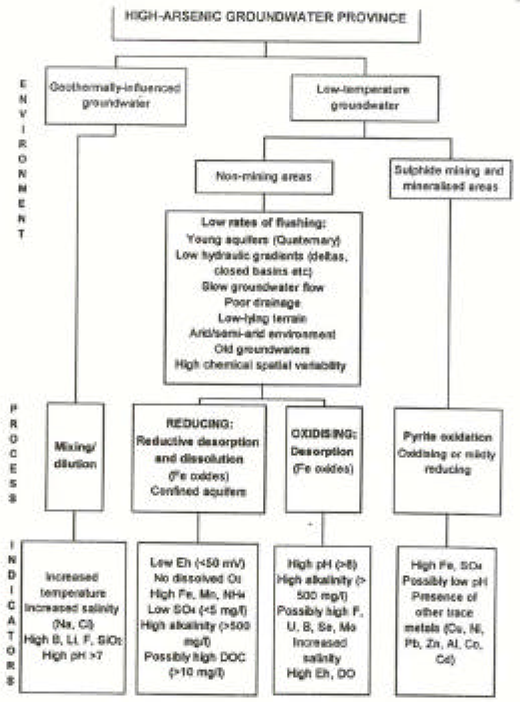


Figure 2. Flow diagram to assist identification of potential high-arsenic groundwater provinces (DOC; dissolved organic carbon, DO: dissolved oxygen. Eh: redox potential)

which involves the reduction of arsenite and arsenate by zinc to give arsine gas which is then used to produce a stain on mercuric bromide paper. There have been many studies of the sensitivity and reliability of these kits, particularly in India and Bangladesh. They are usually good at detecting high concentrations (greater than around 100 μg $1-^{1}$) but despite claims, have rather poorer reliability at lower con-centrations. Few would claim that they are reliable enough at concentrations of less than 50 μg $1-^{1}$, the critical range for drinking waters. Stringent quality control of analyses using field- test kits needs to be carried out by laboratory cross-checking.

There are a number of new developments in field-test kits but probably the most promising is the' Arsenator Light' developed by Professor Walter Kosmus of the Karl Franzens University, Graz, Austria. This is a logical development of the standard Gutzeit kit in that it replaces zinc with sodium borohydride and so removes the problem of obtaining low-arsenic zinc; uses tablets instead of liquid chemicals and so avoids the need for carrying strong acids in the field; has a simple and robust arsine generator; has improved sensitivity and precision, uses a calculator-style device to measure the stain developed photometrically rather than by eye and is easily calibrated. The kit is still being developed with the support of UNICEF, Bangladesh.

Remediation techniques and supply of low-arsenic drinking water

A number of solutions to the arsenic problems of vulnerable aquifers have been suggested for different situations. The only clear conclusion is that no single solution is appropriate for all problems.

Identification of safe tubewells

In areas where groundwater-arsenic problems may be suspected but data are lacking, a broadscale randomised survey of selected tubewells is required to identify the scale of the potential problem.

In areas of known arsenic problems such as Bangladesh and West Bengal, identification of safe tubewells is being carried by rigorous water testing (laboratory and field tests) of sources used for drinking, as well as periodic monitoring to ensure long-term safety. Even in severely contaminated areas, not all wells within a given aquifer are contaminated (greater than the national standard concentration). Hence groundwater should not be abandoned completely without further evaluation. In Bangladesh, a British Geological Survey study has shown that of some 3500 groundwaters collected nationally, 25% were above 50 μg 1-^{1} and 35% above 10 μg 1-^{1} (Kinniburgh and Smedley, 2000). There is also the possibility of selective use of contaminated sources (for washing etc). However, in some areas, a high percentage of tubewells may be contaminated and alternatives therefore need to be found.

Groundwater treatment

The most commonly used methods of treatment of high-arsenic waters at community and municipal level are by the addition of coagulants such as alum or potassium permanganate. Alum is readily available in most countries but has the drawback of leaving residual aluminium and sulphate in treated waters and is not very efficient for waters above pH 7.5. Alum is being promoted for domestic use in Bangladesh using a two-bucket (alum and sand) system. Potassium permanganate is also added to reducing groundwaters to oxidise arsenite to arsenate and thereby facilitate its removal Adsorption of arsenic to the manganese oxide produced also occurs. Ferric chloride is also used, but more so in western countries because of cost. The efficacy of the various treatments depends on a number of factors, including the original arsenic concentrations and the overall water chemistry . Activated alumina is also used in some areas to remove arsenic by adsorption, though this is also expensive and not so suitable for developing countries. Both alum and activated alumina are also commonly used to remove fluoride (see Fluoride Fact Sheet).

For anaerobic groundwaters, there may be some benefit from simple natural flocculation of iron present in the water which precipitates as iron oxide upon aeration. This may be done by simply leaving water for a period (overnight) to allow aeration and settling. Where arsenic concentrations are high and/ or arsenic:iron ratios are high, this will be less effective but while the method may not remove the arsenic completely, it will certainly help. This method is not effective for aerobic groundwaters because iron concentrations are usually low.

Treatment of affected groundwater in Bangladesh and West Bengal is also being tried at household level using pots with various adsorption media (e.g. sand, gravel, clay) with varying success.

In oxidising aquifers with high pHs, arsenic is often not the only water-quality problem. Water treatment may also require salinity reduction alongside removal of other problem elements such as fluoride, boron, uranium, vanadium and selenium. Where possible, reverse osmosis is commonly carried out to remove these constituents, but the method is expensive and not suitable for village-level treatment in poor communities.

Alternative tubewell siting

In Bangladesh and West Bengal, older aquifers at greater depth (> 150 m) have mainly low arsenic concentrations and have in places been developed for drinking-water supply. The great spatial variability in arsenic concentrations also offers some possibilities for alternative siting. Potential for alternative tubewell siting, either spatially or with depth therefore arises in some vulnerable aquifers. However, spatial and depth variations in arsenic concentrations are not universally predictable in different aquifers. For example, the occurrence of low-arsenic ground- waters at depth in parts of Bangladesh and West Bengal is specific to the region and cannot be used as a rule of thumb elsewhere. This approach requires a detailed knowledge of the hydrogeological and geochemical conditions of the local aquifers. Provision of deeper tubewells involves significant extra cost. The current extent of understanding of spatial variations on a local scale probably does not allow accurate prediction of the locations of low-arsenic groundwater sources spatially.

Use of hand-dug wells in reducing aquifers

In reducing (anaerobic) aquifers, it has often been found that shallow open hand-dug wells have low arsenic concentrations whilst tubewells only a few metres deeper have much higher concentrations. The difference is probably due to maintenance of aerobic conditions in the open well and also to regular flushing 0£ the shallowest parts of the aquifer, close to the water table, by inputs of recent rainwater. Low arsenic concentrations are typical of hand-dug wells in Bangladesh and West Bengal as well as in Ghana. The problem arises with bacteriological quality 0£ open dug wells, as they are more vulnerable to pollution from the surface. Such sources require bacterial disinfection for potable use. UNICEF (India) has developed a sanitary well system with a well cover, hand pump and chlorination pot for this purpose.

Rainwater harvesting

In areas with sufficient rainfall, collection and storage of rainwater for potable use may be possible, at least seasonally. The method involves collection of rainwater either from roofs or with sheets of plastic and storage in large cement tanks. Once in the tank, rainwater can be stored safely without bacterial contamination for several months. Rainwater harvesting has been practised for a long time in many coastal areas, island communities and other areas where aquifers are saline. It is now also being tried in arsenic-affected areas, for example parts of Bangladesh.

Treated surface water

Surface water usually has low arsenic concentrations (generally much less than 10 μg 1^{-1}) but may suffer from serious bacterial contamination and can cause severe health problems if not treated. Use of pond sand filters is being tried to remove bacteria in some areas. These usually involve filtration of surface water through a sand- and gravel-filled tank. Such filters are being installed for example by UNICEF in parts of Bangladesh. The filters are generally effective, provided they are periodically cleaned.

On a larger scale, urban piped-water supplies distributing treated river water are being installed in some arsenic-affected areas (e.g. West Bengal). This is however expensive and not suitable immediately for many large, dispersed and rural communities.

Data sources

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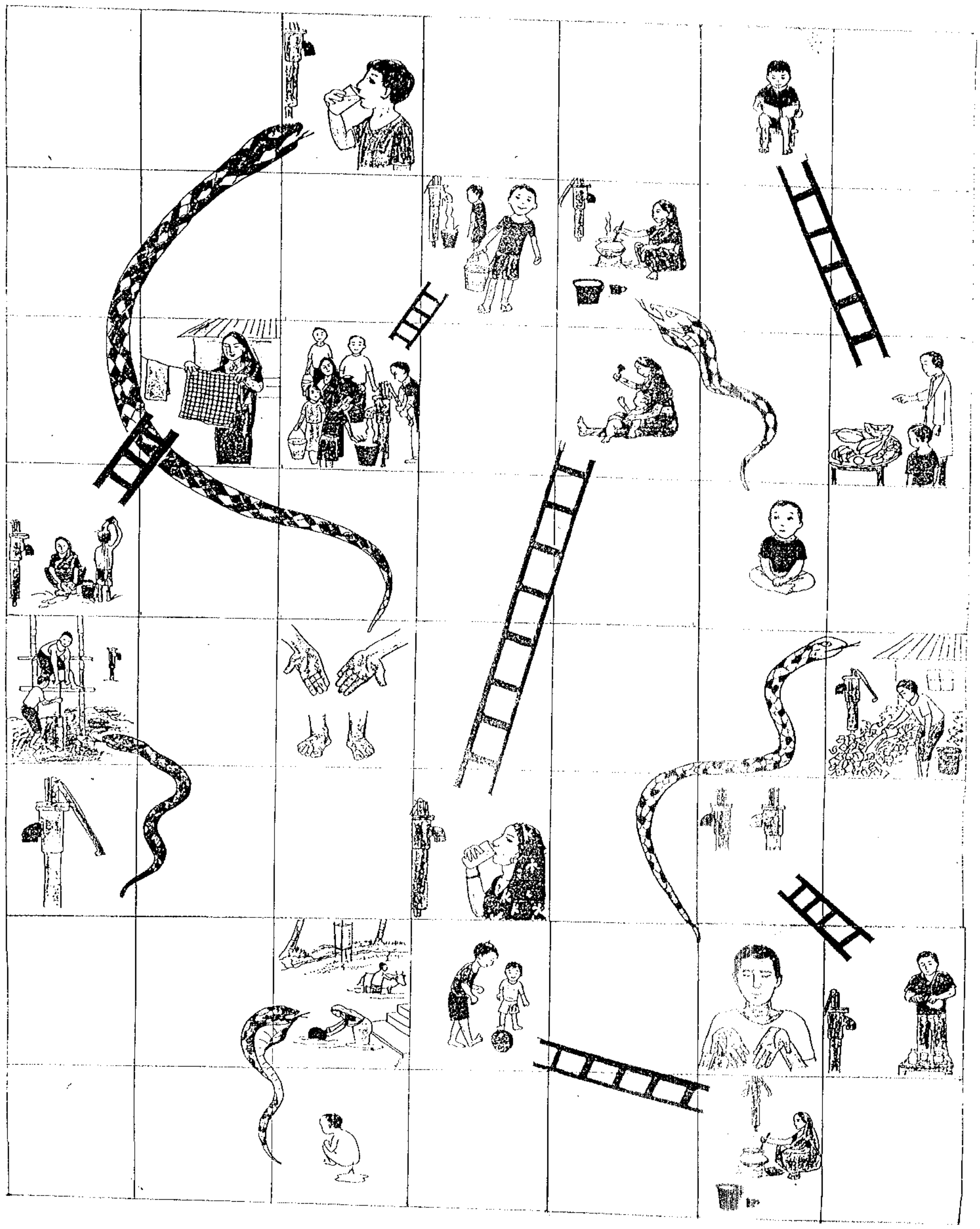
British Geological Survey, 2000.

ANNEXE 6

WaterAid Bangladesh Participatory Arsenic Awareness Tools

FROM : WATERAID BANGLADESH PHONE NO. : Oct. 31 1999 04:25PM P01



Annexe 7

FROM THE SODIS WEB SITE

What is SODIS?

- A treatment method to eliminate the pathogens which cause water-borne diseases
- Ideal to disinfect small quantities of water used for consumption
- A water treatment process depending on solar energy only
- An alternative water treatment option for use mainly at household level
- An old but so far hardly applied water purification method

Limitations of SODIS

- SODIS does not change the chemical water quality
- SODIS does not increase the water quantity or reduce water shortages
- SODIS is not useful to treat large volumes of water
- SODIS requires relatively clear water (turbidity less than 30 NTU)
- SODIS needs solar radiation
  (exposure time: 5 hours under bright or up to 50% cloudy sky, or 2 consecutive days under 100% cloudy sky)

The Process

Diarrhoeal diseases may be transmitted through contaminated drinking water and cause the death of over three million people annually. Solar water disinfection (SODIS) can contribute to improve this precarious situation. So far, two different processes using solar energy for water treatment have been developed independently.The first focuses on solar water disinfection by radiation, and the second applies solar thermal water treatment. Extensive laboratory and field tests conducted by EAWAG and its partners revealed that synergies, induced by the combined application of radiation and thermal treatment, have a significant effect on the die-off rate of the microorganisms. Hence, the best use of solar energy is, therefore, the combined application of the two treatment processes. Field tests also revealed that Vibrio cholerae are effectively inactivated by solar water disinfection.

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Ueberlandstrasse 133
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Annexe 8

Emergency Arsenic Response
Prepared by the informal arsenic emergency task force (July 2000)

It may be noted that over the last six months several appeals have been made at LCG for emergency action and an Emergency Task Force had been formed. This generic proposal is the result of the inputs made by the various members of the Task Force.

WORK/MOBILISATION APPROACH

Who will do it, where will it be done, what will be done and how will it be done. The selection criteria and a quick mobilisation approach need to be setup.

Defining a 'hotspot': selection criteria
The emergency action will cover 'hotspot' villages which are defined as villages with at least one patient identified with visible symptoms and having at least 70% tubewells above permissible limit for arsenic (50ppb).These areas will be selected from information provided by NAMIC, BAMWSP and the Mapping of 'hotspot' villages. Hotspot areas where there is no project activity maybe prioritised. Based on NAMIC data base Thana maybe identified with at least 1 hotspot village. Hotspots where little has reached affected families-where they do not have access to at least one safe water source and to urgent nutritional (micro-nutrients, vitamins etc.) and medical care maybe selected. Areas where large organisations and other donors are already working need not be included since they already have resources to mobilise.

Where will it be done: in a thana with at least on hotspot village
- Emergency action in thana with at least 1 hotspot village where there is no project.
- Emergency action in hotspot thana having project with partial coverage
- To based on NAMIC data base, Mapping Hotspots

When will it be done: Within 6 months of commencement
The emergency action program will have been completed ideally within 3/4 months(September-December). A flexibility time frame of upto a maximum of 6 months maybe considered if there is a strong need.

Who will do it: Mobilisation Approach:
- Emergency Steering Committee

The co-ordination and steering of the emergency action and implementation plan shall be the responsibility of the Emergency Steering Committee. These committee members will consist of the core Emergency Force and representatives from the following major organisations/departments:

1. BAMWSP: Mr. Fariduddin
2. World Bank: Mr. Minnatullah
3. Core EmergencyTask Force:
4. Ainun Nishat (IUCN)
5. Han Heijnen (DPHE-WHO)
6. H. Tabatabai (GTZ)
7. Sharmeen Murshid (Brotee)
8. Elizabeth Jones (Water Aid)

Emergency Implementing Teams- Local and International development agencies/NGOs/PVDOs/CBOs
The Steering Committee will select local non government organisations, private development agencies and community based organisations of the respective selected areas to implement the emergency program through Emergency Teams.

3. HOW AND WHAT NEEDS TO BE DONE: ACTIVITY PLAN

The emergency action program will have three essential thrusts:

1. Screening tubewells:
Tubewells (shallow and deep) in the selected thana must be tested with field test kits and 10% validated with the AAS method (particularly those which show safe arsenic levels must be cross checked)

2. Provide immediate access to safe water: Options possible

- Deep tubewell (1000ft. and above):
- Surface water filter plant
- Community level As removal technology
- Household level As removal technology (e.g. Kolshi filter, SODIS etc.)
- Rain water harvesting
- Protected hand dug well
- Any other available surface water technology (, pond sand filter etc.)

Emergency Teams will demonstrate how to install and operate these. They will distribute iron filings for Kolshi filter, bucket etc, and work closely with village/community and union parishad so that the work continues after Teams depart.

3. Provide emergency medical care to the affected:
One or more Emergency Mobile Doctor's Teams similar to Medicines sans Frontieres (perhaps even jointly with the help of such an organisation) need to visit 'hotspots' throughout the emergency period. Local doctors will work with the team during local travel for the continuation of the service. Emergency Team will provide supply to village bodies/union parishad/health staff etc. micronutrients, vitamins for arsenic affected people.

- Referral for seriously affected patients
- Symptomatic medical relief for the less affected:
  -Distribute vitamins A, E, C, B
  -Provide micro-nutrients and ointment

4. Vital information dissemination
An Emergency Team will go out to the village and inform community on the status of tubewells and on any of the above mentioned safe options made available to them. They will demonstrate how to install and operate simple technologies.
Re-enforcement of basic messages using existing IEC material developed by BAMWSP and others and through radio, microphone and meetings.

- Do not drink from red tube wells
- Drink from green ones and allow others to share
- Improve diet to include some protein and take vitamin supplement
- Collect rain water for drinking and cooking.
- Demonstrate:
  -Households level arsenic removal technologies
  -Community level arsenic removal technologies
  -Surface water filter
  -How to collect rain water
- Announce dates of arrival of doctors teams
- Explain external symptoms and refer to health centers

In all cases NGOs, CBOs will mobilise the village community and work closely with the Steering Committee and with local health staff and DPHE.

Annexe 9

Detail on Household Level Arsenic Removal Technologies

TECHNOLOGY	**PASSIVE SEDIMENTATION**
Process	Sedimentation – co-precipitation with iron on oxidation
Chemical controls	Relies on passive coagulation with iron Main control is iron in the water PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Duration of settling Final water could be contaminated by stirring Bacteriological contamination could be an issue
Operating procedure	Fill kolshi and leave to settle for over 12 hours. Pour top 2/3^{rds} for use and discard lower 1/3rd.
Flow rate - low turbidity - high turbidity	N/A N/A
Time for 20 litres to pass	12 hours (depends on size of kolshi – 12 hrs = 30l kolshi)
Litres in 12 hours	20 litres (depends on size of kolshi – 20 litres = 30l kolshi)
Batches before deterioration - low turbidity - high turbidity	 N/A N/A
Claims on effectiveness (Results and references)	2 out of 17 wells tested took As below 50ppb. Greatest influence seen was negative correlation between As removal and Electrical Conductivity. Water Aid, March 2000. Household Level Arsenic Removal Methodologies, Preliminary Research Report.
Costs (capital and recurrent)	20 litre aluminium kolhsi – approx. Tk. 200/-
Contact details	-

Stirling University (UK), VERC, DFID and WaterAid are currently testing this technology.

TECHNOLOGY	**DPHE/Danida Bucket Treatment Unit**
Process	Oxidation/coagulation/filtration
Chemical controls	Relies on enhanced coagulation Less dependent upon groundwater Fe Chemical oxidant enhances arsenite removal PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact Ideal pH 6.5 to 8 for optima functioning of alum Possible residual Mn
Physical controls	Agitation and duration of coagulation Sand packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Pour water into the top bucket. Add mixture of aluminium sulphate and potassium permanganate and stir vigorously 20 times. Leave to settle for 2 hours. Turn tap to send water to lower bucket where it passes through a sand filter. Turn tap in bottom bucket to get drinking water.
Flow rate - low turbidity - high turbidity	70 litres per hour (but 23 l/hr including 2 hours preparation) 50 litres per hour (but 17 l/hr including 2 hours preparation)
Time for 20 litres to pass	Approx. 3 hours (1 hour settling + 1 hour filtration)
Litres in 12 hours	60 litres
Batches before deterioration - low turbidity - high turbidity	 17 batches – no deterioration 40% fall in flow after 6 batches, then constant to 15 batches
Examples of claims on effectiveness (Results and references)	Noakhali – 100% As below 50ppb after treatment (initial levels 120-1000ppb.) DPHE/Danida Arsenic Mitigation Pilot Project Information leaflet 'Arsenic Removal at Household Level' Sitakunda and Gomastapur – 100% As below 50ppb after treatment (initial levels 116-201 ppb) Water Aid, March 2000. Household Level Arsenic Removal Methodologies, Preliminary Research Report.
Costs (capital and recurrent)	Tk. 300-350 depending on the production cost of the flat cover for the lower bucket.
Contact details	DPHE-Danida Water Supply and Sanitation Components, Arsenic Mitigation Component, 2888, Central Road, Harinarayanpur, Maijdee Court, Noakhali. Ph. 0321 5582

The total cost of the 2BTU is Tk 300 (US$ 6.00)
Households buy the reagent from project staff at Tk 10 (US$ 0.10) for a 250g pot that lasts an average household about one month[1].

WATSAN Partnership Project, NGO Forum, VERC, BAMWSP, DFID and WaterAid are currently testing this technology.

TECHNOLOGY	**SONO 3-KOLSHI FILTER**
Process	Filtration
Chemical controls	Relies on passive coagulation with Fe and/or adsorption to sand matrix PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand/iron filings/charcoal packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Pour water into top kolshi. Use water from the bottom kolshi.
Flow rate - low turbidity - high turbidity	Approx. 5 litres per hour Approx. 5 litres per hour
Time for 20 litres to pass	Approx. 4 hours
Litres in 12 hours	Approx. 60 litres
Batches before deterioration - low turbidity - high turbidity	 15 batches with no major deterioration 15 batches with no major deterioration
Claims on effectiveness (Results and references)	As (III) from 800ppb to less than 50ppb (2ppb) As (total) from 1100ppb to less than 50ppb (10ppb) A.H.Khan et al, 'Appraisal of a Simple Arsenic Removal Method for Groundwater of Bangladesh', Journal of Environmental Science and Health, A35(7), 1021-1041 (2000)
Costs (capital and recurrent)	Tk. 325/-
Contact details	Professor A.H. Khan, Department of Chemistry, University of Dhaka, Dhaka-1000, E-mail: ahkhan@du.bangla.net Dr. A.K.M. Munir, Director, SDC-Environment Initiative, College More, Courtpara, Kushtia 7000

This filter mechanism is low cost and readily available in Bangladesh. BRAC, UNICEF, VERC, DFID, BAMWSP and WaterAid are currently testing this technology.
The total cost of the three kalshi unit is Tk 250 to 300 (US$ 5 to 6), of which about 50% is the cost of the metal stand. BRAC have experimented with bamboo and wooden stands, but found that these were even more expensive to produce than the metal stand. The cost of a replacement kalshi, including iron filings and coarse sand, is about Tk 55 (US$ 1.10).
Reference: (##########)

TECHNOLOGY	**STEVENS INSTITUTE TECHNOLOGY**
Process	Coagulation/filtration
Chemical controls	Relies on enhanced coagulation and co-precipitation (ferrous suphate) Less dependent upon groundwater Fe Chemical oxidant (chlorine-based) enhances arsenite removal PO4 > ASO4 >> SiO4 >F High HCO3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand cleaning and packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Collect 20 l in a bucket, add chemicals and stir rapidly for a minute. Pour into filter (bucket with holes on top of sand in larger bucket) and wait for water.
Flow rate - low turbidity - high turbidity	18 litres per hour 18 litres per hour
Time for 20 litres to pass	Just over one hour
Litres in 12 hours	Approx. 240 litres
Batches before deterioration - low turbidity - high turbidity	 Steady decline to 50% initial flow after 10 batches Steady decline to 50% initial flow after 10 batches
Claims on effectiveness (Results and references)	Kachua - less than 50ppb As in treated water (max. 25ppb) from initial As concentrations of 300-800ppb). BAMWSP testing programme Kishoreganj and Munshiganj – max. As was 19ppb from initial untreated concentrations of 280-468ppb. Xiaoguang Meang and George P. Korfiatis, ‘Removal of Srsenic from Bangladesh Well Water by the Stevens Technology for Arsenic Removal (STAR)’. Occasional Paper.
Costs (capital and recurrent)	Tk 500/-
Contact details	Professor Meng, Center for Environmental Engineering, Stevens Institute of Technology, Hoboken, NJ 07030. E-mail: xmeng@stevens-tech.edu Md. Suruzzaman, Earth Identity Project, House 13A, Road 35, Gulshan, Dhaka-1212. Tel: 8812049

The cost of the tablets is estimated at 2 US dollar per family per year. Steven’s Institute has plans to manufacture the tablets locally.

BAMWSP and DFID are currently testing this technology.

TECHNOLOGY	**Ardasha**
Process	Filtration
Chemical controls	Unkown
Physical controls	Character and flow rate through filter
Operating procedure	Pour water into tray within bucket. Use tap to get treated water from bottom of bucket.
Flow rate - low turbidity - high turbidity	1.1 litres per hour 1.1 litres per hour
Time for 20 litres to pass	19 hours
Litres in 12 hours	13 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration in 15 batches No deterioration in 15 batches
Claims on effectiveness (Results and references)	DPHE R& D (Ishtishamul Hoque) have done some assessment and think it reduces As below 50ppb. Not sure why.
Costs (capital and recurrent)	Tk. 550
Contact details	Mr. Sounir Mojumdar, CRS-Ardasha Filter Industries, Chagalnaya Bazar, Chagalnaya, Feni

TECHNOLOGY	GARNET FILTER
Process	Filtration
Chemical controls	Relies on passive coagulation with Fe and/or adsorption to sand matrix $PO_4 > AsO_4 >> SiO_4 > F$ High HCO_3 has –ve impact High Ca/Mg has +ve impact
Physical controls	Sand packing in filter Distribution of water over filter Sand grain size and clays Sand Fe and Organic C content Character and rate of flow through filter
Operating procedure	Water frequently topped up in top bucket. Flow regulated to second bucket – regular checking required.
Flow rate - low turbidity - high turbidity	0.7 litres per hour 0.4 litres per hour
Time for 20 litres to pass	Approx. 30 hours
Litres in 12 hours	Approx. 7 litres
Batches before deterioration - low turbidity - high turbidity	 50% initial flow after 7 batches 30% initial flow after 5 batches
Claims on effectiveness (Results and references)	Removal efficiencies of 70-100% cited in GARNET's own literature, depending on the presence of As and Fe in the feed water.
Costs (capital and recurrent)	Tk.250-600 based on material for stand and containers
Contact details	Shah Monirul Kabir, Programme Officer/GARNET Secretary, GARNET-SA, 1/7, Block-E, Lalmatia, Dhaka-1207, Tel: 9117421

GARNET members, including CARE-Bangladesh, are testing this technology. DFID are also testing this technology.

TECHNOLOGY	**BUET ACTIVATED ALUMINIUM FILTER**
Process	Oxidation, sedimentation, filtration, active alumina
Chemical controls	Semi-reversible adsorption to Al_2O_3 Arsenite removal occurs (through oxidative step)
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 0.1mg/l AsO_4, 15000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Fill top bucket and add chemicals as directed. Stir vigorously and leave for one hour. Turn tap to allow water into the activated alumina column. Retrieve water from bottom of column.
Flow rate - low turbidity - high turbidity	Approx. 8 litres per hour Approx. 8 litres per hour
Time for 20 litres to pass	Approx. 2.5 hours
Litres in 12 hours	Approx. 96 litres
Batches before deterioration - low turbidity - high turbidity	 Steady gentle deterioration (<10% over 15 batches) Steady gentle deterioration (<10% over 15 batches)
Claims on effectiveness (Results and references)	
Costs (capital and recurrent)	Tk. 1000/-
Contact details	Dr. M.A. Jalil, Department of Civil Engineering, BUET, E:mail: majalil@buet.edu

TECHNOLOGY	ALCAN ACTIVATED ALUMINIUM FILTER
Process	Sedimentation, filtration, active alumina (AAFS-50)
Chemical controls	Semi-reversible adsorption to Al_2O_3 Arsenite removal occurs (through oxidative step- chlorine)
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 0.1mg/l AsO_4, 15000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Usually attached to well head and pump directly into the filter
Flow rate - low turbidity - high turbidity	>300 litres per hour >300 litres per hour
Time for 20 litres to pass	3-5 minutes
Litres in 12 hours	>3600 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration No deterioration
Claims on effectiveness (Results and references)	Studies by Department of Chemistry, Dhaka University, and BRAC (Sonargaon) show a removal rate of 100%.
Costs (capital and recurrent)	US$100 (5 year warranty, expected life 10 years). Annual filter material costs US$200. Costs expected to fall.
Contact details	M. Saber Afzal, MAGC Technologies Ltd, House 15, Road 5' Dhanmondi, Dhaka-1205. E-mail: mendota@bdmail.net

TECHNOLOGY	TETRA HEDRON
Process	Ion resin exchange
Chemical controls	Reversible exchange of anions with chlorine Relatively independent of feed As and Fe Potentially affected by competing SO_4 and NO_3 Affinities for ion exchange SO_4>NO_3>ASO_4>Cl-PO_4 not known
Physical controls	Formulae to calculate bed-volumes to exhaustion (for 1mg/l SO_4, 1000 bed volumes) Potentially prone to clogging by FeOH
Operating procedure	Fill first container with feed water (over chlorine tablet), water enters second container and turning the tap at the second container releases the water for. Water supply is almost instant.
Flow rate - low turbidity - high turbidity	90 litres per hour 85 litres per hour
Time for 20 litres to pass	15 minutes
Litres in 12 hours	1080 litres
Batches before deterioration - low turbidity - high turbidity	 No deterioration No deterioration
Claims on effectiveness (Results and references)	Pre-testing through BAMWSP for 50 units installed in Singair, Hajiganj, Urzipur, Gopalganj (50 units in all) suggest complete removal of As from initial concentration of 100-1700ppb.
Costs (capital and recurrent)	Tk. 12000/- plus annual costs of Tk. 6000/- (ion resin column lasts on average for six months)
Contact details	US: Waqi Alam, TETRAHEDRON@prodigy.net Bangladesh: Mr. Wazir Alam or Mr. Altaf, Dhaka Tel: 9882770

ION EXCHANGE RESINS

Manganese dioxide coated sand (MDCS), prepared by reacting potassium permanganate with manganese chloride under an alkaline condition and in the presence of sand, shows promise as a medium for use in small systems or home-treatment units. No leaching of manganese has been detected.

Resin technologies also exist in Bangladesh and are currently being field tested by BAMWSP. The system they use is a simple two bucket methodology with an approximate unit cost of Tk4000.

The local availability of this medium is uncertain, READ-F manufacture a simple two bucket system which is a resin based technology.

RAJSHAHI UNIVERSITY / NEW ZEALAND IRON HYDROXIDE SLURRY

This filtration methodology requires the addition of an iron hydroxide slurry to a three chamber unit. The capacity of the unit is estimated at 100 litres. The top chamber is the mixing chamber which contains the iron hydroxide slurry, and to which raw water is added. In adding water, the slurry is churned up and mixes with water. The water is drained through the middle, second chamber which constitutes a sand filter. After passing through the sand filter the treated water is stored in the bottom, third chamber and is collected by tap.

Four units currently exist in Rajshahi. This technology is being tested by Rajshahi University.
Contact: Richard.Anstisi@aut.ac.nz

SORAS (Solar Oxidation and Removal of Arsenic)

SORAS is a simple method that uses irradiation of water with sunlight in PET- or other UV-A transparent bottles to reduce arsenic levels from drinking water. The SORAS method is based on photochemical oxidation of As (III) followed by precipitation or filtration of As (V) adsorbed on Fe (III) oxides. Some groundwater in Bangladesh contains Fe (II) and Fe (III) and therefore, SORAS could reduce arsenic content and would be available to everyone at virtually no cost. It could be a water treatment method used at household level to treat small quantities of drinking water.

The SORAS method can be applied within a certain range of arsenic concentrations. It has to be carefully introduced in arsenic-affected villages by demonstration projects in which the users are adequately trained and the socio-cultural acceptance of SORAS assessed. In case of successful application, the supply problem of robust plastic bottles in adequate numbers will than have to be studied in order to embark on large-scale programs required to solve the arsenic problem in Bangladesh and in other parts of the world.

SORAS is a simple arsenic removal process applied at household level with locally available resources. However, the arsenic removal efficiency is limited to approx. 50 - 70 % and hence, raw water up to 100 - 150 μg/L can be treated with this low cost method. Arsenic affected people are desperately waiting for water treatment options which have to be developed and promoted by the different actors of the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP). SORAS is such an option, at least it is a useful interim measure until better options might be available. Faced with the choice between drinking water that contains 150 and more μg/L of poisonous arsenic, or after treatment by SORAS, water that contains half or a quarter of that amount, who would not opt for the later ? Furthermore, SORAS also removes the iron and improves the taste of the water to which people attribute a high interest.

The SORAS method is now ready to be applied within a certain range of arsenic concentration. It has to be carefully introduced in arsenic-affected villages by demonstration projects in which the users are adequately trained and the socio-cultural acceptance of SORAS assessed. In case of successful application, the supply problem of robust plastic bottles in adequate numbers will than have to be studied in order to embark on large-scale programs required to solve the arsenic problem in Bangladesh and in other parts of the world.

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ARSENIC / IRON REMOVAL PLANTS

A number of organisations working in geographical areas with the problem of high iron concentrations in drinking water have designed and constructed community level iron removal plants. In areas that are also effected by high arsenic concentrations the arsenic removal rates of these iron removal plants have been monitored.

Organisations that have piloted this arsenic removal methodology include:

- 18 District Towns Project
- Rotary International / UNICEF
- DPHE / DANIDA
- NGO Forum for safe drinking water and sanitation

SIDCO

AdsorpAs® is an Adsorbent developed by M/S HARBAUER GmbH, Berlin in co-operation with the Technical University of Berlin, Germany.

SIDCO claim that studies on the adsorption of both arsenic forms (AsIII & AsV) on different adsorbents have determined that granular activated ferric Hydroxide with high specific surface has 5 to 10 times higher efficiency for adsorption of Arsenic from water than other adsorbents.

The main application of AdsorpAs® is the adsorptive removal of arsenate and arsenic. Arsenic binds on the surface of AdsorpAs® by chemiesorption process forming a stable surface complex with ferric hydroxide. AdsorpAs® does not require chemical regeneration and does not produce any regenerate sludge. The residual mass of the spent AdsorpAs® is small.

The adsorption technique with Granular Ferric Hydroxide in fixed bed reactor is simple, safe and effective method for elimination of arsenic from contaminated groundwater. Depending on the concentration of arsenic in raw water 50,000 to 70,000 bed volumes can be treated with Granular ferric Hydroxide.
SIDCO claim that the system is cost-effective. The running/operating cost of the AdsorpAs® system for removal of arsenic from drinking water having a 250 ppb Arsenic concentration is less than 1.0 paisa (US$0.02) per liter of guaranteed arsenic below the WHO (10ppb) recommendation level in water.

Organisations currently tting this technology include BRAC , CRAE, Rotary International, UNICEF, DPHE and Proshika. This technology is also utilised in India (M/S. Pal Trockner [P] Ltd.) by PHED, Govt of West Bengal, to remove Arsenic from ground water.

Contact: *Mir Moaidul Huq, General Manager, Sidko Limited*
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ALCAN Activated Alumina Filter

A process of sedimentation, filtration and active alumina with the system usually attached to well head and pumped directly into the filter. Approximate flow rates of >300 litres per hour. Approximate capital cost US$100 (5 year warranty, expected life 10 years). Annual filter material costs US$200. Costs are expected to fall. Studies have been carried out by Department of Chemistry, Dhaka University, and BRAC (Sonargaon). Within a 12hour timespan >3600 litres can be treated.
Contact: M. Saber Afzal, MAGC Technologies Ltd, House 15, Road 5' Dhanmondi, Dhaka-1205. E-mail: mendota@bdmail.net

Arsen-X System

Arsen-X adsorbent is an inorganic matrix which selectively adsorbs and binds targeted compounds. The media will bind arsenic, chromium, selenium and ferric cyanide. Arsen-X is claimed to be suitable for either dose or flow through systems. Arsen-X also claims to produce a very low sludge volume. The pH value of the treated water will increase slightly when Arsen-X is working enabling a monitoring systems other than testing for arsenic concentrations to be put in place.
Contact: *Ostertech Inc. 37 North Forge Drive, Phoenixville, Pennsylvania 19460, USA*

Phone / fax: +610 935 066
Email: lewo@att.net

?READ-F
Contact: #######

TETRA HEDRON
Ion resin exchange mechanism. Fill first container with feed water (over chlorine tablet), water enters second container and turning the tap at the second container releases the water. Water supply is almost instant. Flow rate approximately 85 litres per hour Pre-testing through BAMWSP (a total of 50 units installed in Singair, Hajiganj, Urzipur, Gopalganj) suggest good removal of As from initial concentration of 100-1700ppb. The capital costs are approximately Tk. 12000/- plus annual costs of Tk. 6000/- (the ion resin column lasts on average for six months)
Contact: *US: Waqi Alam, TETRAHEDRON@prodigy.net, Bangladesh: Mr. Wazir Alam or Mr. Altaf, Dhaka Tel: 9882770*