1

INTRODUCTION

1.1 Background

Bangladesh made great strides in improving coverage of its population with access to an improved water supply and in the Global Water Supply and Sanitation Assessment 2000 Report (WHO and UNICEF, 2000), Bangladesh had a coverage in rural areas of 97% of the population having access to an improved water supply within one kilometre of their home or 30 minutes total collection time. The presence of arsenic in groundwater is now reduced this figure to 74% and in the mid-term assessment of progress towards meeting the MDG Target for water, Bangladesh was considered off-track (WHO and UNICEF, 2004). It should be noted, however, that in other countries currently considered to be on-track to meet the MDG, it is likely that if water safety is taken into account then progress would be lower. Nonetheless, arsenic in shallow groundwater has resulted in a major water supply and public health problem for Bangladesh and one that requires ongoing and urgent attention.

The scale of the problem of arsenic contamination of drinking water in Bangladesh has become increasingly well understood since arsenic was first over 10 years ago. It is now a national concern with grave consequences upon human lives and productivity. Ever since the first identification of arsenic contamination of groundwater in 1993 at Chapai Nawabganj in Rajshahi Division, a number of major initiatives have been undertaken at different times to address different issues related to the problem. The Government of Bangladesh (GOB) has initiated and implemented a number of major programmes, with support from development partners and a range of national and international NGOs. Mitigation programmes have included the implementation of a national tubewell screening by BAMWSP and other stakeholders, awareness-raising programmes in the affected Upazilas, implementation of pilot level mitigation programmes, finalisation of a protocol for patient identification and management, and a number of research projects. In 2004, GOB published National Policy for Arsenic Mitigation and an Implementation Plan for Arsenic Mitigation in Bangladesh as a guide for future mitigation efforts.

1.2 Government Initiatives

From the outset, the GOB has addressed arsenic contamination as a serious issue and initiated a number of projects and programmes in different parts of the arsenic contaminated areas for combating the problem. A number of programmes have been initiated by GOB to specifically address arsenic, including the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) and the DPHE-Unicef 45 Upazila programme.

National level activities have been conducted throughout the country to complete tubewell screening in the 271 worst affected Upazilas, awareness-raising campaigns and patient identification. Mitigation options have also been installed, although at a more limited scale. BAMWSP and DPHE-Unicef have also strengthened the capacity of the different government officials of different levels to deal with various aspects of the arsenic problem and its solutions. BAMWSP also renovated and established new zonal laboratories across the country to strengthen the capacity of water quality monitoring capabilities of DPHE. The National Arsenic Mitigation Information Centre (NAMIC) was established by BAMWSP for collecting and storing and disseminating information related to arsenic problem, NAMIC has developed a information based website (www.bamwsp.org) to make information accessible. BAMWSP formed several community based organizations (CBOs) for active participation of communities in combating arsenic.

BAMWSP is the largest of the specific arsenic mitigation programmes and was initiated in 1998 with the financial assistance of the World Bank and the Swiss Agency for Development and Cooperation (SDC). This was implemented through the Department for Public Health Engineering, Local Government Division of the Ministry of Local Government, Rural Development and Cooperatives. In addition, other large GOB programmes like GOB IV and DPHE-Danida have also provided arsenic mitigation through more general water supply programmes.

The DPHE-Unicef programme is a community based pilot arsenic mitigation project in different highly contaminated upazilas undertaken by DPHE with the financial assistance of UNICEF and involving national and local level NGOs and Local Government Institutions. Initially, this programmes started with 5 upazilas, which was expanded to 15 upazilas in 2001 and then later to 45 upazilas in 2002, with an integrated approach for creating awareness among the people, screening of wells, identification of patients and providing alternative safe water options in the contaminated area. Dug (ring) wells, pond sand filters, rainwater harvesting, deep tubewells and piped water supply systems were provided as alternative safe water options.

In south-eastern part of Bangladesh DPHE with the financial assistance of DANIDA has undertaken arsenic mitigation through the DPHE-DANIDA project. The project is working in five districts. A number of deep tubewells were installed in coastal region and arsenic contaminated area as an alternative source of safe water supply.

The Bangladesh Water Development Board, under the Ministry of Water Resources, have undertaken hydrogeochemical investigation of deep aquifers in different parts of the country with the Geological Survey of Bangladesh. Initially BWDB started the programme in different upazilas of Madaripur and Noakhali districts.

In order to deal with the problem with utmost importance at the highest level of the government an Inter-Ministerial Secretaries Committee on arsenic was formed by the Government of Bangladesh chaired by the Principal Secretary. A National Committee of Experts (NCE) was also formed to support the Secretaries Committee on technical matters related to arsenic problem. The NCE was a multidisciplinary panel of experts of different academic institutions, research organizations, government and non-governmental agencies. These two committees oversaw the preparation of the National Policy for Arsenic Mitigation and Implementation Plan for Arsenic Mitigation in Bangladesh, which was approved by the Cabinet in 2004.

BOX-1

Secretaries Committee

Chairman:

Principal Secretary

Members

Secretary, Ministry of Agriculture
Secretary, Economic Relation Division
Secretary, Ministry of Health and Family Welfare
Member (Physical Infrastructure), Planning Commission
Secretary, Ministry of Environment and Forest
Secretary, Local Government Division
Secretary, Ministry of Water Resources
Secretary, Ministry of Science and Technology
Chairman, Bangladesh Atomic Energy Commission
Chairman, Bangladesh Council of Scientific and Industrial Research
Director General, Department of Health
Director General, Department of Environment
Director General, Geological Survey of Bangladesh
Chief Engineer, Department for Public Health Engineering

Named experts

Mr. S. K. M. Abdullah
Professor M. Feroze Ahmed
Professor Ainun Nishat
Professor Kazi Qamruzzaman
Professor Mahmudur Rahman
Dr. A Z M Zahid Hossain
Professor Mujibur Rahman

The committees have now been combined into the National Arsenic Policy Implementation Committee - or National Arsenic Committee

(NAC) for short - which is chaired by the Principal Secretary and includes both technical experts and policy makers. The Ministries represented on the NAC are presented in Box 1.

The Directorate of Health Services (DGHS) under the Ministry of Health and Family Welfare worked with UNICEF in eight Upazilas for the screening of arsenicosis patients. DGHS has developed the arsenic patient identification and patient management protocols with the financial assistance of WHO. The DGHS provided almost 2,000 doctors and 20,000 field health workers for diagnosis and management of arsenicosis patients and conducted awareness campaign through the Government health care providers.

To support the policy implementation, the Local Government Division established the Arsenic Policy Support Unit (APSU) with the financial assistance of DFID to support coordination among the organizations on various aspects of the arsenic and sound policy implementation. APSU is also assigned to help the development of a national arsenic mitigation programme (NAMP) through a partnership approach.

There have been a number of smaller projects, for instance Bangladesh Rural Development Board under the Ministry of Local Government and Rural Development and Cooperatives, has completed a pilot project with the financial assistance of Sida in four Upazilas of two districts. Dug wells, rainwater harvesting were the principal options installed in the project area.

From the start of arsenic mitigation activities, arsenic removal technologies have been developed within the country and others were imported from other countries. These technologies are now verified through an environmental technology verification programme-arsenic mitigation (BETV-SAM). This programme is implemented by the Bangladesh Council of Scientific and Industrial Research (BCSIR) under the Ministry of Science, Technology and Communication with the financial assistance of CIDA. The first phase of the BETV-SAM, provisional verification was given to four technologies and the second phase started in 2005.

In addition to these programmes and projects, a number of international workshops, seminars, symposiums and discussion sessions have been arranged by different government and non-government organizations, institutions and universities. Experiences and critical findings as well as recommendations and suggestions were presented on different issues of arsenic problem in those events.

1.3 Non-governmental Initiatives

Beside the government initiatives a number of international and national NGOs (INGOS and NNGOs), National and International Universities have also undertaken initiatives for combating the arsenic problem in different parts of the country. With support from development partners, Asia Arsenic Network, World Vision, the NGO Forum for DWSS, Dhaka Community Hospital, BRAC, Care Bangladesh, IDE Bangladesh and WaterAid Bangladesh have been engaged in different arsenic related activities. Some of these organizations engaged several other local NGOs and organizations for conducting the field level activities like awareness campaigns, tubewell screening, patient identification and arsenic mitigation.

The NNGOs and INGOs have a made a significant contribution in mass communication for creating the awareness among the people regarding the risk of drinking arsenic contaminated water. A number of good communication materials such as TV, radio features, posters, flipcharts, stickers, bill boards have been developed. Most of the NGOs have been working with close coordination with the government organizations at national and local levels.

Several action research programme and projects have also been conducted. The Bangladesh University of Engineering and Technology (BUET), International Training Network-BUET, Dhaka University, Jahangirnagar University, Rajshahi University, Columbia University, Texas University, Cornel University, CIMMYT United States Geological Survey and British Geological Survey have undertaken some critical research into the source of contamination, alternative safe water supply options and characterisation of the Pleistocene aquifer. The results have been disseminated in different international and national seminars.

1.4 Development Partners

Development partners have been providing financial and technical support to government organizations, INGOs, NNGOs and research institutions in addressing arsenic contamination. The principal development partners that have provided support are World Bank, SDC, Sida, AusAID, DANIDA, UNICEF, JICA WHO, UNDP, USAID, DFID, Rotary Club, MISERIOR and NIEHS.

1.5 Need for a Position Paper

Much has been achieved in relation to arsenic mitigation in Bangladesh. The screening programmes have provided valuable information that has allowed a more reliable and accurate estimates of the magnitude of the problem to be made. The screening of about five million tube wells within a few years was a major achievement. The impact of awareness-raising and the development of pilot activities and protocols have laid a sound foundation for undertaking future mitigation programmes. The development of a Policy for arsenic mitigation has provided a sound and effective framework for dealing with the arsenic problem.

These large and diverse initiatives have not been adequately and comprehensively documented and reported on a national basis. As a result, there are sometimes accusations that very little have been done to face the challenges of arsenic related problems in the country. Therefore, there is a need to prepare a comprehensive position paper on the activities, findings and outcomes of the researches, studies and arsenic mitigation efforts in Bangladesh. Government and other stakeholders can use this document in demonstrating how Bangladesh has and is continuing to combat the arsenic crisis. In this context, APSU engaged a local consultant to work under the guidance of key experts with a long experience in the sector (including DPHE, academics and representatives of NGOs) to prepare a position paper. As the knowledge about arsenic contamination and mitigation is continuously increasing, it is expected that as the time passes the paper will need updating to reflect on-going initiatives.

1.6 Outline of the Position Paper

The position paper contains two sections. The first section contains the main report and second section contains different annexes for supporting information. The main report contains six chapters. The first chapter introduces the issue emphasizing the background and different government and NGOs initiatives on arsenic mitigation. The second chapter presents the water sources, type of uses, extent of contamination in soil and food, and its impact on plant and human life. The third chapter reviews the past and current arsenic mitigation initiatives of government, development partners and NNGOs and INGOs. APSU plans and programmes are reviewed in the fourth chapter and a summary of the National Policy for Arsenic Mitigation (2004) formulated by the Government of Bangladesh is presented. Finally, major future and emerging issues are presented in the fifth chapter of the main report.

The second section contains six annexes of project and programme information, technology information, working organization’s information, level of tubewell contamination, who is doing what and publication produced with a brief summary.

2

STATUS OF ARSENIC CONTAMINATION

2.1 Natural Water Sources, Types and Uses

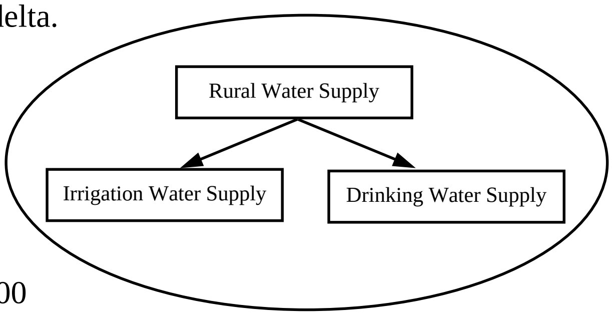
There are three categories of naturally occurring water sources: groundwater; rainwater; and, surface water. Groundwater occurs under much of the world's surface, but there are great variations in depths at which it is found, its quality, the quantities present and rates of recharge. Groundwater is usually of good microbial quality. However, groundwater can easily become contaminated from sources of contaminants such as pit latrines, garbage dumps, animal sheds and cemeteries and through poorly constructed wells. In many areas of the world, groundwater is the principal source of drinking water because it is accessible at relatively low cost and low-cost simple technologies have been developed that allow many local drillers to sink tubewells. Drinking water supplies using groundwater are also often relatively easy to operate. In Bangladesh, the withdrawal of groundwater has been increasing over the past three decades. Around 95% of the groundwater abstracted is used for irrigation and only 3% is used for drinking purposes.

Rainwater collection from roofs or larger catchment areas can be utilized as a source of drinking water. The collection system depends on geographical locations, availability of manpower and cost of construction. The taste of rainwater is different from groundwater and surface water because it contains fewer chemicals. Although rainwater collection is relatively simple, there are problems in some communities in ensuring a year-round supply and it is relatively common to have seasonal shortages of water. Microbial water quality in rainwater tanks may also deteriorate in the dry season.

Surface water, in streams, lakes and ponds are readily available in many populated areas, but it is almost always polluted. Dug wells and ponds were once the major source of drinking water in the rural areas of Bangladesh. Rivers, ponds, khals, contained water round the year although small fluctuation occurred in the water table. The consumption of contaminated surface water was a major cause of the very high levels of mortality and morbidity from diarrhoea and the provision of shallow tubewells of good microbial quality significantly contributed to reducing the disease burden. The increasing population, use of ponds for fish-farming, increasing use of fertilisers and pesticides, and silting of rivers and canals and infilling of ponds are all increasing problems for the quality and quantity of surface water. Many smaller rivers and canals are not perennial and despite large volumes of water in the monsoon have low flows in the dry season.

The provision of arsenic-safe water is essential for Bangladesh to safeguard the health of the rural population. However, the seasonal unavailability of some surface waters and rainwater, the contamination of surface water and community attitudes makes for a very complex situation in the rural drinking water supply sector.

2.2 Hydrogeological setting



Bangladesh located in the Ganges-Brahmaputra delta. The hydrology of Bangladesh is characterized by three major rivers; the Ganges, the Brahmaputra and the tributaries forming the Meghna. The country experiences a heavy rainfall during the Monsoon, generally more than 1500 mm annually (Sheesh, 2000). The result is abundant surface water in the monsoon, which is usually polluted and requires treatment involving clarification, filtration and disinfection. As the rainfall is highly seasonal, the flow in many water bodies decreases significantly in the dry season.

Most of the country is underlain by sedimentary deposits containing aquifers. This water requires a little treatment for acceptable microbial quality and is used by public water utilities and private institutions as the major source of water supply. People have become used to the use of groundwater for drinking water supplies because of the low cost; year-round availability, simple withdrawal mechanism and because the materials and manpower to sink tubewells are available throughout the country. Consequently, the development of drinking water supplies from the shallow aquifer is sustainable where arsenic is not found.

The switch to tubewell water was a revolution in water drinking habits in Bangladesh. Although initially many households were not keen on tubewell water, now nearly everybody in rural areas drinks water from tubewells, which have mainly been sunk by individual households employing local private sector drillers. An analysis of data collected in the DPHE-Unicef project area in fifteen upazilas of Bangladesh reported that 88.1% tubewells are privately owned of which 84.8% is used for domestic purposes and 3.2% used for irrigation purposes (Rosenboom, 2004). An estimated 50% of shallow tubewells have been installed in last 5-6 years. DPHE assisted by

UNICEF, WHO, other development partners and NGOs all provided important contributions in developing low-cost technology and providing water supplies to poor rural communities.

The chronic shortage of food production in Bangladesh led the government in the early sixties to initiate several programmes to improve crop production and expand irrigation. Among the steps taken was the strengthening of agricultural sector institutions including establishment of Bangladesh Agricultural Development Corporation (BADC) in 1961 (Rahman and Ravenscroft, 2003). Initially the BADC started with low-lift pumps from shallow tubewells for cultivation of high yielding variety of rice. A rapid increase in exploration of groundwater for irrigation occurred in response to a shift in government policies to emphasise private trade and investment in the irrigation equipment.

Prior to 1986 the groundwater development was controlled by the public sector through a system of regulation and control of the minor irrigation equipment. Following the liberalization and deregulation in the sale of imported pump sets in 1986 and withdrawal of tubewell restrictions in 1998, the area under STW irrigation was almost doubled from 0.7 Mha in 1886-87 to 1.35 Mha in 1991-92. After the equipment sale liberalisation in 1986 a reassessment of ground water development was done by NPO Phase-II and showed that the number of deep tubewells, shallow tubewells and manually operated shallow tubewells for irrigation had increased to about 23,000, 258,000 and 350,000 respectively. By 1993 the figure had arisen to further 34,000 and 398,000 for deep tubewells and shallow tubewells respectively.

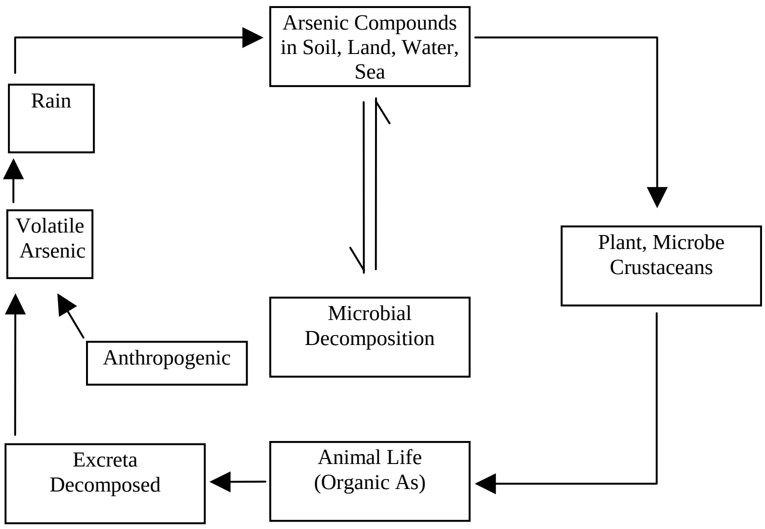


Figure 2.2: Biological Cycle of Arsenic

2.3 Chemistry of Arsenic

In order to adopt an appropriate mitigation strategy an understanding of arsenic chemistry and mobilization scenario is essential. Until 1983, arsenic was only ranked as the 51st most abundant element in the earth’s crust; following widespread monitoring in 1990 arsenic was re-classified as the 20th most abundant element. The average concentration of arsenic in the earth’s crust is about 2 mg/kg. Arsenic is a major component of 245 minerals. Arsenic occurs extensively in fossil fuel and is preferentially found in marine sediments. The Biological and Geochemical Cycle (Ullah, 1996) of Arsenic is given in Figures 2.2 and 2.3.

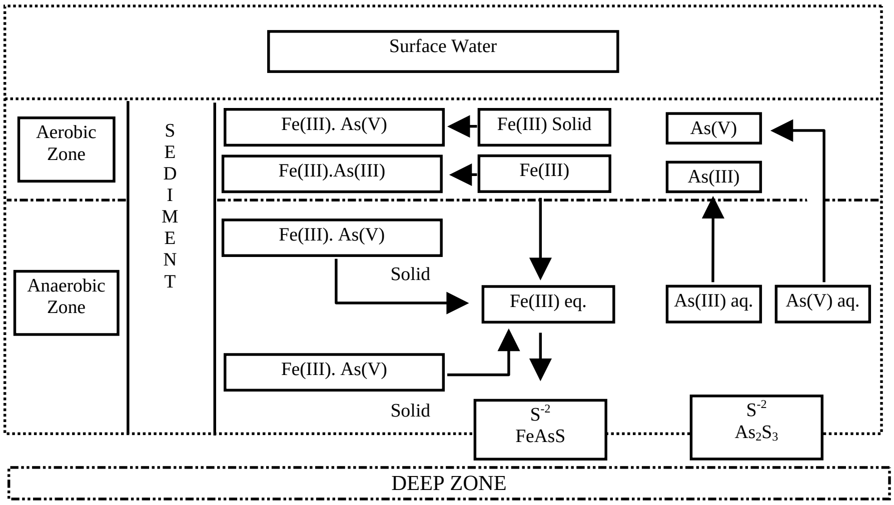


Figure 2.3: Geochemical Cycle of Arsenic

Arsenic has the chemical symbol As. It is a semi-metallic element from group 5A in the Periodic table with an atomic number of 33. and an atomic weight of 74.92. Chemically, arsenic is intermediate between metals and non-metals. Its properties lie, in general, in the middle of the series formed by the family of the elements nitrogen, phosphorus, arsenic, antimony, and bismuth. When arsenic is heated, it sublimes, passing directly from solid to gaseous form at 613 °C (1135 °F). The common form of arsenic is grey, metallic in appearance, and has a specific gravity of 5.7. A yellow, non-metallic form of arsenic also exists and has a specific gravity of 2.0.

2.3.1 Hydrogeochemistry of arsenic

Once the arsenic rich sediments are deposited in the flood plains, the mobilization of arsenic is primarily governed by the prevailing geo-chemical environment. A complex interaction among a number of chemical and physiochemical factors occurs (Safiullah, 1998). Key chemicals play an important role in the mobilisation of arsenic. Prominent among these are labile organic matter, which includes carbohydrates and various glucoses. Humic acids which retain arsenic and fulvic acids which mobilise arsenic are important factors. Amongst the metals iron, calcium, manganese and aluminium are important geo-chemical factors in mobilisation process. The presence of sulfide (S^{-2}) is important in influencing mobilisation and physiochemical factors such as groundwater pH, redox potential, dissolved oxygen and grain size of the aquifer are also important. The movement of arsenic in different spheres (Bhumbla and Keefer, 1994) of the environment, i.e. air, water and soil biota are presented in the Figure 2.4. Movement of arsenic in the different spheres can be either from natural process or by anthropogenic activities.

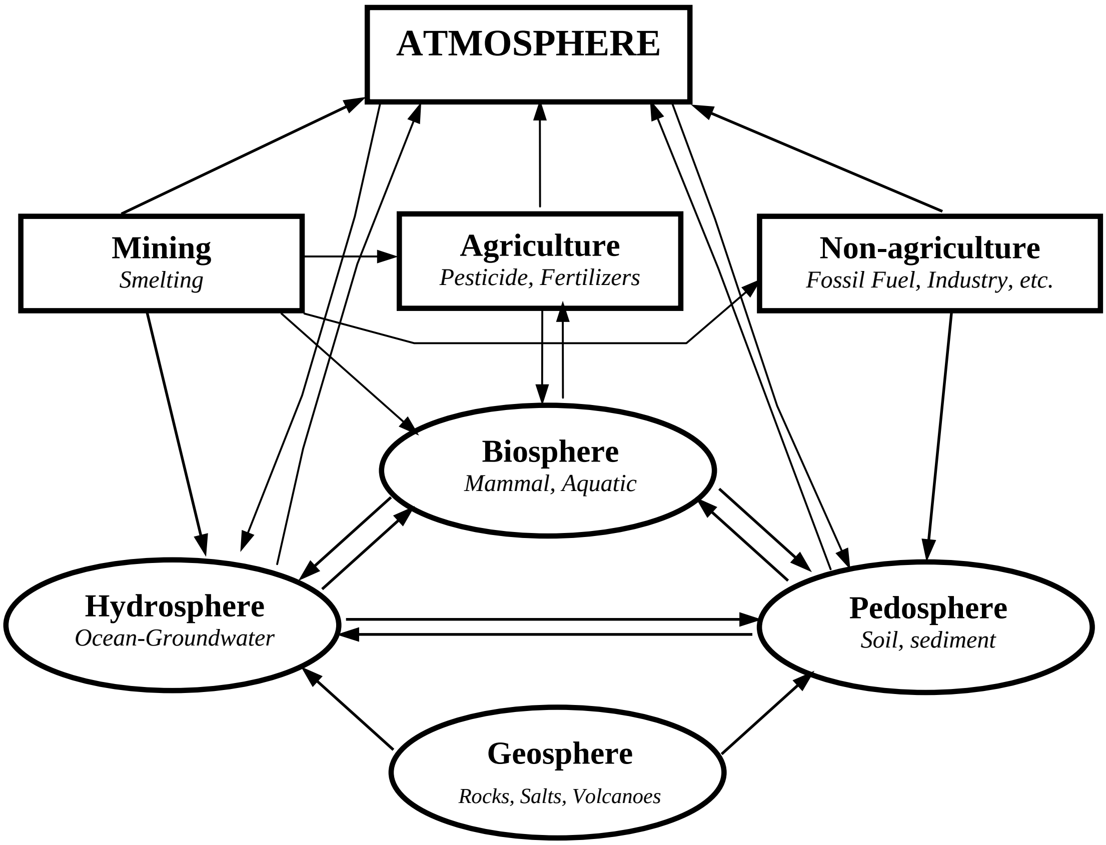
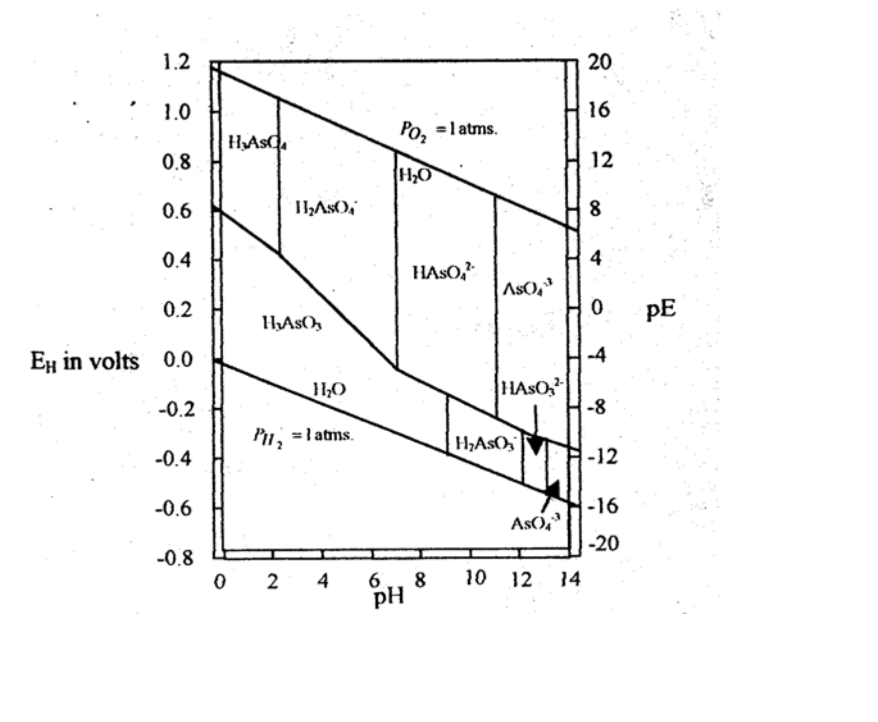


Figure 2.4: Environmental cycle of arsenic

Arsenic occurs naturally in all environmental media and is usually present in the form of compounds with sulphur and with many metals, such as copper, cobalt, lead and zinc. Although arsenic exists in various valency states and in both organic and inorganic forms, the levels of environmental arsenic are normally reported in terms of total arsenic. Arsenic is a naturally occurring water contaminant of water that originates from arsenic containing rocks and soil and is transported to natural waters through erosion and dissolution. Arsenic occurs in natural waters in both organic and inorganic forms, but inorganic arsenic is predominant in natural waters. The valance species of inorganic arsenic are dependent on the oxidation-reduction conditions and the pH of the water.

The reduced trivalent form of arsenic As (III), called arsenite, is normally is found in anaerobic or reducing groundwater and the oxidized pentavalent form As (V), called arsenate, is found in surface water and aerobic groundwater. In some groundwater, both forms have been found together in the same water source. Arsenate exists in four forms in aqueous solution based on pH: H_3AsO_4, $H_2AsO_4^{-}$, $HAsO_4^{2-}$ and AsO_4^{3-}. Similarly arsenite exists in five forms; $H_4AsO_3^{+}$, H_3AsO_3, $H_2AsO_3^{-}$, $HAsO_3^{2-}$ and AsO_3^{3-} (Ketith *et al.*, 2000). Geochemical mobilization is commonly interpreted in terms of their response to pH and eH (the thermodynamic redox



potential). The important species in ground water are the oxidized arsenate and the reduced arsenite oxyanions. Figure 2.5 represents the speciation or arsenic at 25$^{\circ}C$

Figure 2.5: Fields of stability of dissolved form of arsenic at 25°C
Source: Keith et al, 2000

2.4 Possible Causes of Arsenic Contamination of Shallow Groundwater

A number of mechanisms regarding the release of arsenic into the environment have been proposed by different scientists at different times. These are summarised very briefly here. The pyrite oxidation hypothesis suggests that pyrite and arsenopyrite are deposited as pockets in the aquifer sands and are oxidised and released into the groundwater. The oxidation is initiated by the entry of air into the aquifer due to lowering of water table, which occurs because of the large abstraction of groundwater for irrigation. In this hypothesis, the oxidation of pyrite and arsenopyrite will increase the concentration of sulphate along with the arsenic. However, the arsenic contaminated groundwater of Bangladesh typically shows very low concentrations of sulphate. Moreover, no significant relationship was observed regarding the increase of concentration of arsenic in highly irrigated areas. The analysis of long term hydrographs of different areas showed that there is no significant relationship between the arsenic contamination and the fluctuation of groundwater tables.

The iron oxyhydroxide hypothesis suggests the source, release mechanism and transportation of arsenic in the Bengal Basin was controlled by the sedimentation history. During the sea level drop in the last ice-age about 7,500 years ago, the rivers of the basin were incised 150m below the present level. This initiated an intensive weathering of the Rajmahal Hills, Choto Nagpur Plateau, the Himalayas and the Shillong Plateaus. Sulphide minerals containing iron and arsenic were oxidized and dissolved into the river water. The dissolved arsenic was absorbed from the river by iron/manganese/aluminium hydroxides under oxidizing condition during sediment-water interaction in the river. These arsenic contaminated sediments along with the abundant organic matter were deposited into the alluvial plains of Bengal Basin. The organic matter consumed the oxygen and conditions changed from the initial oxidizing to a reducing environment. Under reducing conditions, arsenic was released into the groundwater and thus high arsenic concentrations are found in reducing groundwaters. Field data for arsenic show a negative correlation with sulphate and a positive correlation with iron, bicarbonate, manganese and phosphorous.

The presence of high organic matter plays a very significant role in the arsenic release mechanism in the Bengal Basin and the presence of high ferrous iron, low nitrate, sulphate and biogenic methane indicates the highly reducing condition of the aquifer. Taking all these into consideration a tentative mobilization scenario is shown in Figure 2.6. Not all these pathways in this mobilization scenario have been studied to date. Some crucial redox release mechanisms are being examined. It is entirely possible that processes such as auto-catalytic redox reactions are also involved in this scenario so that concentration of the total arsenic and the inorganic speciation finally appear as a result of some kind of organization of electrodynamics at soil water interface of the aquifer. In geochemistry such as self-organization has been observed in the iron oxide-manganese oxide (Fe_2O_3/MnO_2) band formation in mud and sediments (Jacob and Dietrich, 1998).

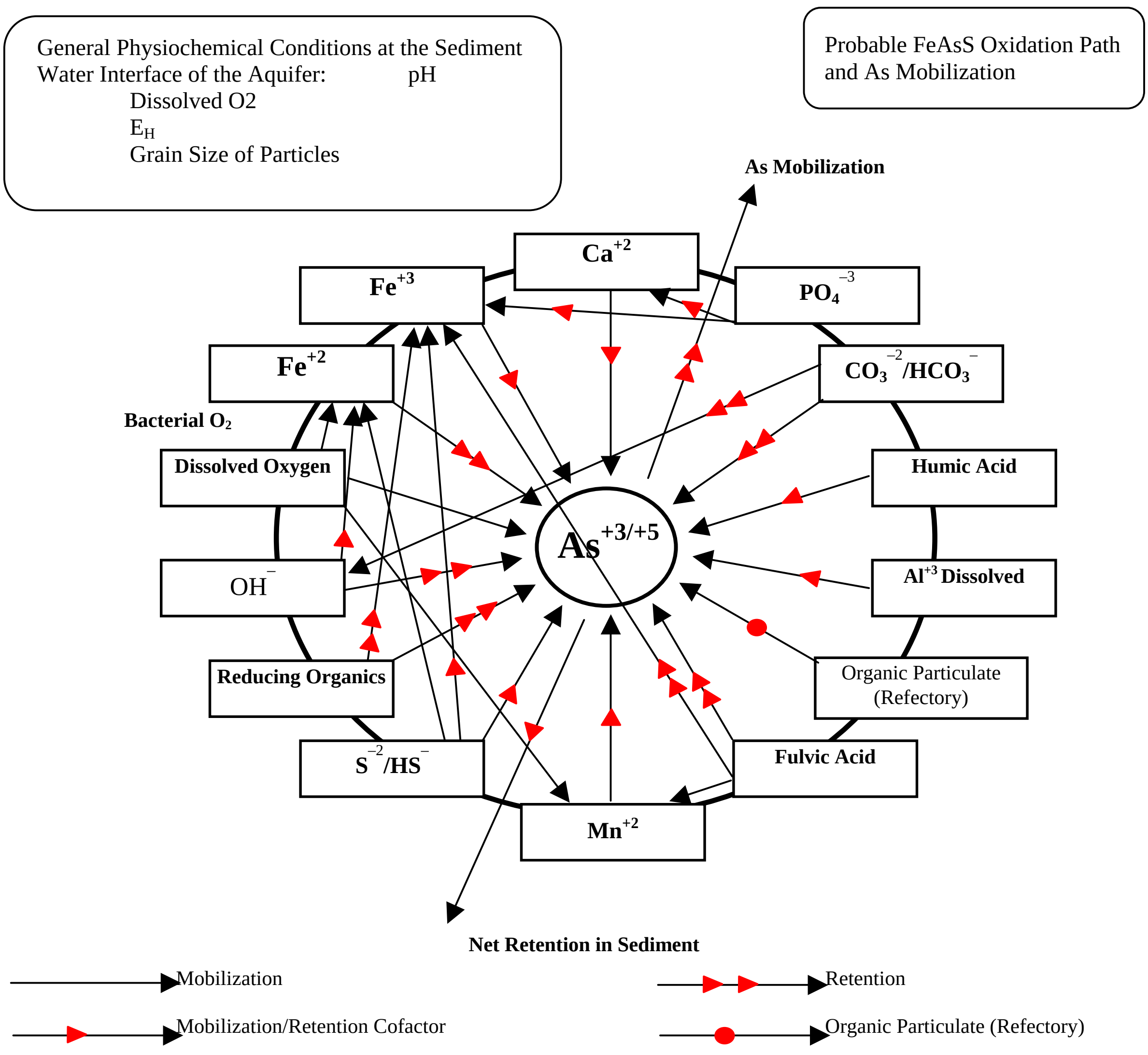


Figure 2.6: Tentative Interrelationship Scenario of Arsenic Mobilization Factors at Sediment Ground Water Interface

Source: Safiullah 1998

2.5 Geographical Spread and Intensity of Arsenic Contamination

The first national survey of arsenic contamination in Bangladesh was undertaken by the Department of Public Health Engineering, British Geological Survey and Mott-MacDonald in 1998-9 with support from the UK Department for International Development (DFID). This survey was designed to provide a representative sample of water supplies tested for arsenic across the country to obtain a clear picture of the overall national scale of the arsenic problem (BGS and DPHE, 2001). The survey tested 3,534 tubewells across the country and covered all 61 plain land Districts. Data from other programmes, including the DPHE National Hydrochemical Survey (which excluded the Chittagong Hill Tracts) were also reviewed and analysed.

The survey found that 27% of the shallow tubewells (defined within the survey as a depth of less than 150m) had arsenic in excess of the Bangladesh Standard of 50µg/l and 46% exceeded the provision WHO Guideline Value of 10 µg/l. Of the deeper tubewells (depth over 150m) only 1% exceeded the Bangladesh Standard and 5% exceeded the provision WHO Guideline Value, although the sample size was small (327 tubewells)[1]. Subsequent studies have suggested that there are greater rates of arsenic contamination of deep tubewells in specific areas. The survey suggested that arsenic contamination was concentrated in the shallow aquifers of up to 150m (roughly 500 ft) depth, although the highest average contamination was found in the 15-30m (50-100ft) range. The very shallow aquifer of below 15m (50ft) appeared to be largely arsenic free, although subsequent studies have shown significant arsenic contamination in shallow dug wells (Rosenboom, 2004).

The BGS-DPHE survey indicated the southern and eastern part of Bangladesh is most heavily contaminated and where people were most at risk. The survey provided a preliminary indication of the population exposed using two methods and calculated that between 28 and 35 million were exposed to concentrations above the Bangladesh standard and between 46 and 57 million were exposed to concentrations above the provisional WHO Guideline Value. The survey noted the significant spatial variation in arsenic concentrations in arsenic and a map was prepared which is shown in Figure 2.7. The survey also found that boron, manganese, barium, chromium and ammonia were other chemical parameters of concern.

The screening of all operational tubewells in the 271 worst arsenic affected Upazilas was initiated by the Government of Bangladesh through six major programmes with partner organizations:

1. the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) undertaken by the Department of Public Health and Engineering (DPHE) with support from the World Bank and SDC initiated in 1998.
2. the DPHE/DANIDA programme Arsenic Mitigation Component
3. the DPHE/UNICEF arsenic mitigation programme
4. Asia Arsenic Network, a Japanese NGO with support from JICA
5. WATSAN Partnership Project with support from SDC; and
6. World Vision Bangladesh.

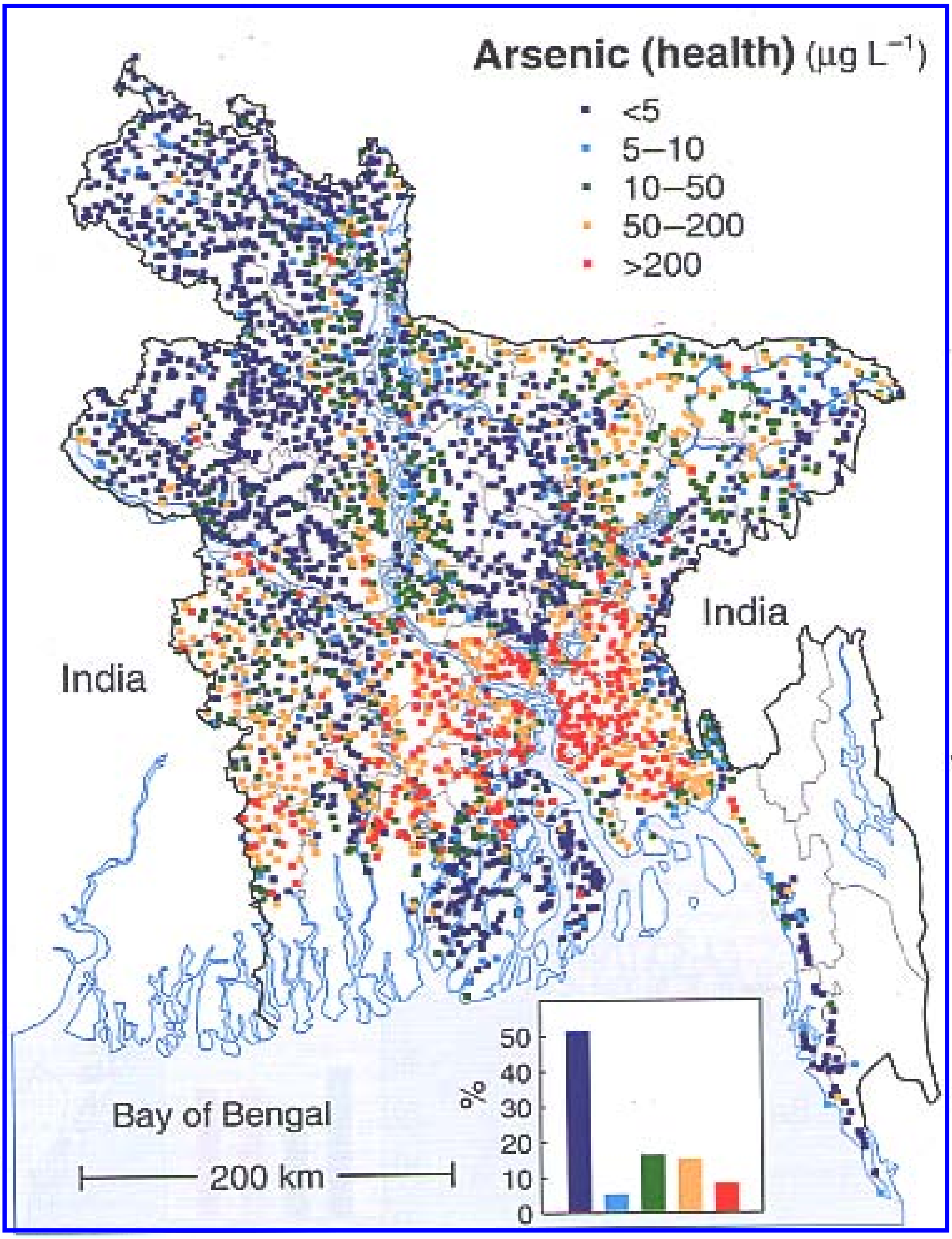


Figure 2.7: Status of arsenic contamination of ground water of Bangladesh, 1999. (Source: BGS and DPHE, 2001)

A total of 49.47 lakh tubewells were screened out of which 14.40 (29.12%) lakh exceeded the Bangladesh standard (BAMWSP, 2004). It is not possible to estimate the numbers of tubewells exceeding the Provisional WHO Guideline Value because the field test kits used do not reliably measure to the level required. The screening confirmed that the intensity of arsenic contamination of groundwater is much higher in the South-western and South-eastern part of Bangladesh. Details are presented in Figure 2.8. BAMWSP project also conducted a survey of arsenic contamination of well of different Pourashavas and the findings are presented in Figure 2.9. The villages where more than 80% of tubewells are contaminated above the Bangladesh standard, and Upazila wise contamination percentage is presented in Annex D.

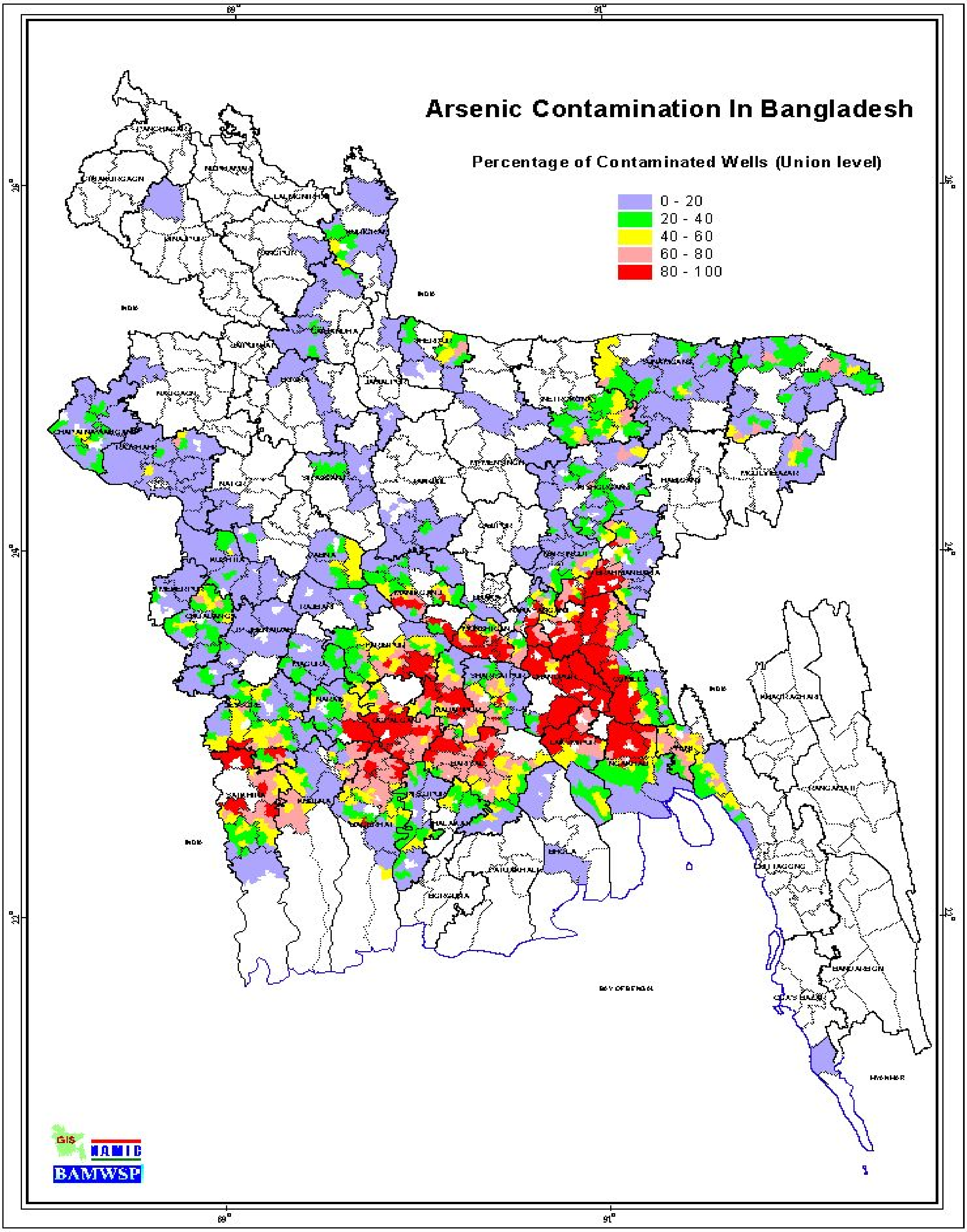


Figure 2.8: The distribution of arsenic in ground water of Bangladesh, BAMWSP (2004)

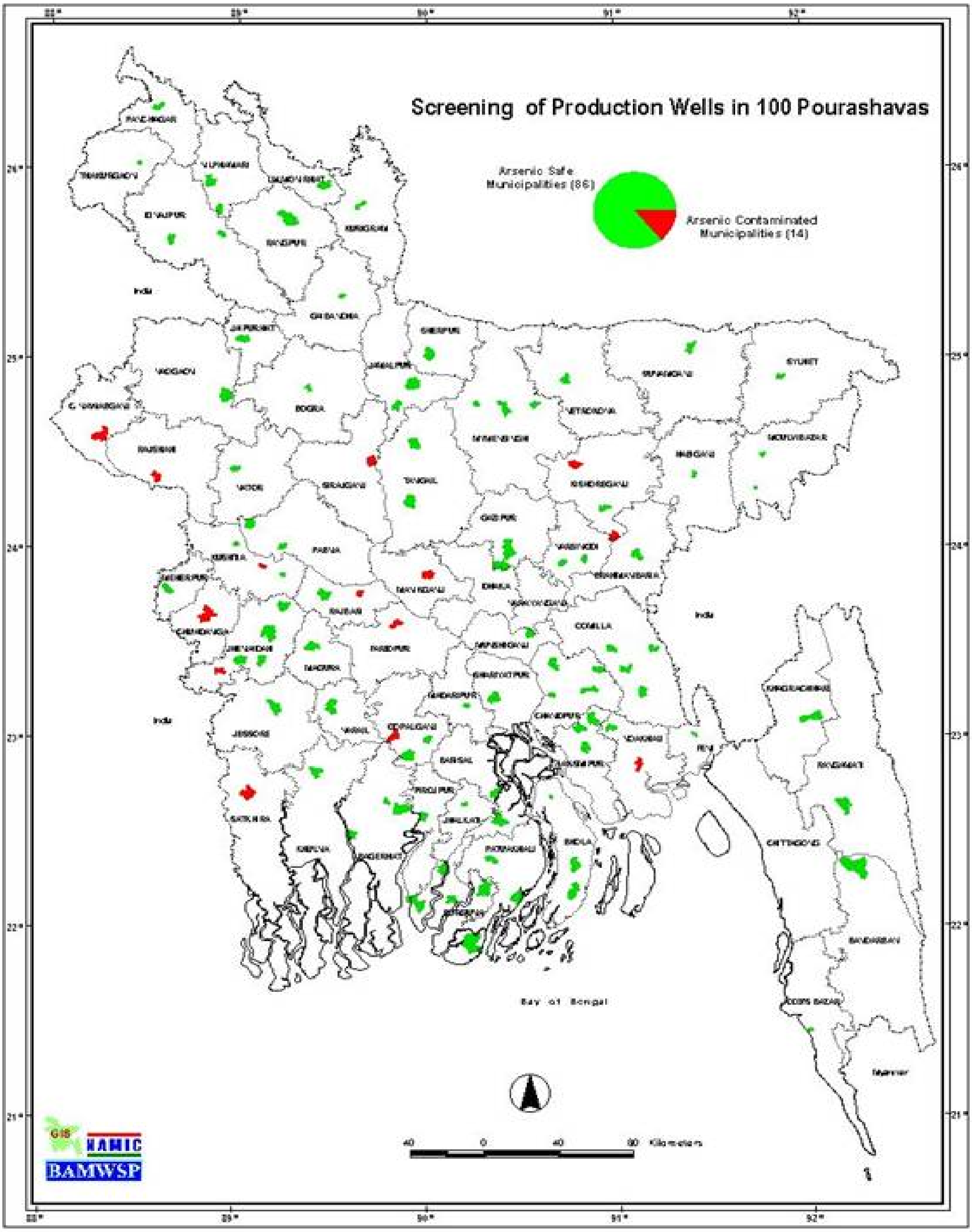


Figure 2.9: Results of arsenic testing of production well of 100 Pourashava along the country, BAMWSP(2004)

The figures from the screening programme, which covered approximately half the country, suggest that the scale of the problem is less than originally estimated by the BGS-DPHE-MM survey. Although the exact number of tubewells in the country is not known, it is estimated in be in the region of 8-10 million. Using a figure of 9 million tubewells in Bangladesh, the screening data suggests that overall rates of arsenic contamination of tubewells is of the order of 15-20% of all tubewells in the country.

The tests for arsenic in the screening programme were performed using field test kits, primarily the Merck and HACH EZ test kit. The NIPSOM kit is also used in some areas for testing of tubewells. Training was provided to field staff before undertaking the screening. The use of field kits was justified because there were insufficient laboratory resources in Bangladesh capable of undertaking arsenic analysis within the time required to deliver final data. Subsequent cross-checking of field kit data with laboratory data has suggested that overall the level of accuracy and reliability of the test kits was reasonable (Rosenboom, 2004). However, the accuracy and reliability improved over time, suggesting that earlier results are likely to be more questionable. It is also true to say that while the overall accuracy was good, individual tests may well have not been accurate.

APSU conducted a rapid review of nine arsenic field test kits commonly available in Bangladesh (APSU, 2004). The study reported that the test kits showed a wide variation of results from tests of two different locations with different groundwater quality. The reported that there were a number of other problems related with use of the field kits, including handling errors, reagent errors, method errors and visual detection errors. It was recommended that these could be minimized by employing trained and skilled manpower; using an electronic reader based colour detection apparatus with regular standardization of the reader; and, quality control of the reagents. The report noted the importance of operator of kits and their level of commitment, knowledge about the testing, the sensitivity of the kit and its chemistry, and ability to compare test colours with the comparator chart. The importance of cross checking options for checking results and standardization of test kits was also highlighted.

A report of an inter-country consultation report on the verification of arsenic mitigation technologies and field test methods stated that several models are now able to measure arsenic in drinking water at levels below 10μg/l. They urged for quality control and quality assurance procedures to ensure the validation of field results by laboratory based measurements (WHO/SEARO, 2003).

2.6 Impact on Human Health

The risk to human health under most environmental conditions is primarily concerned with the positive trivalent (+3) and pentavalent (+5) forms of arsenic. Zero valent arsenic is highly insoluble and is not absorbed by human tissue. The negative trivalent (–3) form of arsenic is arsine gas, which does not a cause of significant environmental exposure although it does represent a significant hazard in the analysis of arsenic (IPCS, 1981). Whether the arsenic is in an organic or inorganic form is important when assessing exposure because the organic form is considered to be of very low toxicity. Inorganic arsenic species dominate in water and therefore exposure to arsenic from drinking water is primarily to the most toxic forms. There is substantial evidence in animals that arsenic is an essential trace element, but very little data is available to show that this is the case for humans. For instance, currently the US Food and Nutrition Board of the National Research Council does not accept arsenic as an essential element for humans (NRC, 1994).

The acute and chronic effects of arsenic exposure are very different. Acute arsenic poisoning leads to a number of symptoms including severe gastroenteritis shock, neuro-toxicity and peripheral vascular failure. The acute lethal dose for arsenic in humans has not been calculated precisely, but has been estimated to be between 70 to 300 mg. Arsenic may produce direct irritant effects on gastrointestinal tissues with which it comes in contact. Sub-acute arsenic poisoning from lower doses of arsenic may result in dry mouth and throat, heartburn, nausea, abdominal pains and cramps, and moderate diarrhoea. Chronic low-dose arsenic ingestion may cause mild esophagitis, gastritis, or colitis but in other cases does not result in any symptoms of gastrointestinal irritation. Chronic effects caused by arsenic produce a variety of skin effects and in the longer-term mutagenic effects can result in cancer or other problems in the exposed generation.

The USEPA used Taiwan skin cancer data to estimate the non-cancer health effects from arsenic. The USEPA standard default procedure is to assume a threshold generally estimated from the No Observable Adverse Effect Level (NOAEL), the concentration at which no health effects are observed and then incorporating an uncertainty factor. A similar process is followed by the World Health Organisation in establishing Guideline Values for toxic chemicals. Where no NOAEL can be established, WHO sets Guideline Values based on the Lowest Observable Adverse Effect Level (LOAEL) (WHO, 2004).

Figure 2.12 shows several different possible dose-response relationships for arsenic that can be used to determine acceptable levels of arsenic exposure. The USEPA used the linear relationship, and linear-quadratic function to fit the Taiwan ecological skin cancer data (USEPA, 1988). The second set of curves represent alternatives that probably cannot be distinguished from the linear and linear-quadratic relationship in the region between 100 and 500 μg/day. The threshold relationship has a sharp cut-off with no increase in disease over background below a threshold shown in the figure at 500 μg/d. The non-linear relationship decreases towards background more slowly, with no apparent increase over background below 200 μg/d and increasing up to the level of the threshold relationship between 200 and 700 μg/d. All four relationships are consistent with an assumed high-dose data point at 1000 μg/d of 2.8% lifetime cancer incidence.

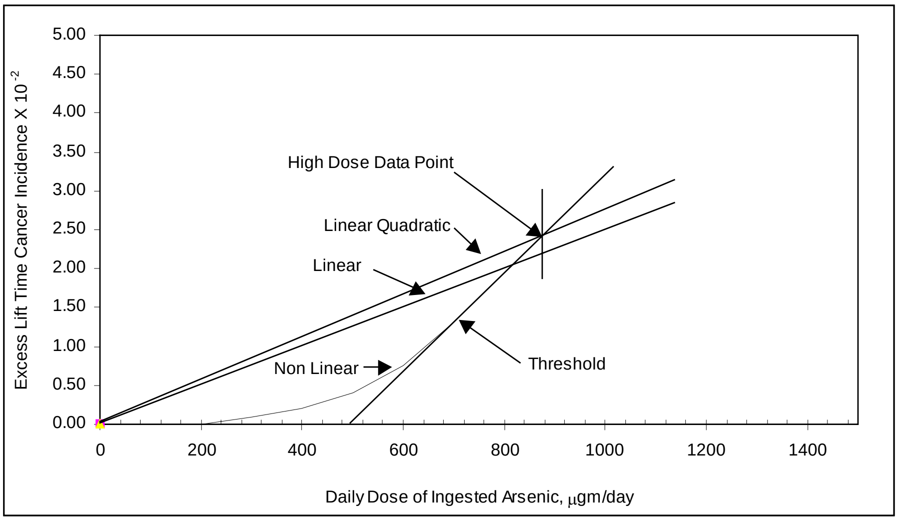


Figure 2.12: Different types of dose response relationship of arsenic

Single cell studies have established that specific forms of arsenic can be cytotoxic. It is generally considered that arsenic toxicity results from the inhibition by trivalent arsenic of enzymes containing sulphydryl. In most cases, the enzyme activity can be restored by adding an excess of monothiol such as glutathione, suggesting that the inhibition is due to a reversible reaction of arsenic with single sulphydiryl group in the enzyme molecule (Shafi, 1999).

Globally the interest in the health risks of exposure to inorganic arsenic has been primarily focused on carcinogenic effects and in particular the development of skin and lung cancer, although there is increasing interest in other adverse health effects and a number of epidemiological studies are underway to investigate these. Other studies have suggested that there are links between arsenic exposure and cancer of the liver, kidney and prostate (Abernathy, 2001). Peripheral vascular disease and cardiovascular disease have been associated with the arsenic in drinking water. The occurrence of blackfoot disease after arsenic exposure has been extensively documented as have a range of skin conditions. There also appears to be a link between arsenic in drinking water and an increased risk of diabetes mellitus and hypertension

(Rahman, 1999). Ongoing work is also investigating the impact of arsenic exposure on cognitive and intellectual development of children and shows that there may be adverse effect (Wasserman *et al.*, 2004), although the number of studies to date is small and the evidence not conclusive.

The first symptom of arsenocosis is melanosis, where the limbs of the body have brackish/dusky appearance and then rest of the body is affected. Gradually black and white spots appear on the body, a stage known as spotted melanosis. The spots may then become hardened and result in keratosis. This is not painful or ichy in the beginning but in the later stage may start rotting and develop into gangrenous ulcers, the pre-cancerous stage. The hardening of palms and soles of the feet is called diffuse keratosis. Wart-like seeds can grow on the keratosis of palms and soles. Tumours may also occur, which is known as spotted keratosis. Due to the arsenic toxicity limbs may be affected by gangrenous ulcers, which in some cases result in amputation of the affected limb. General weakness, burning sensation, hot flush and chronic coughs may also affect patients.

The provision for arsenic safe water, antioxidants such as vitamins A, C and E and keratolytic ointment helps the improvement of skin manifestations of the chronic arsenicosis. Early detection of internal organ involvement including cancer and early treatment can increase the possibility of reducing mortality from arsenic-related cancers.

Patients often do not seek help for arsenicosis until it has become serious and arsenicosis it often difficult to differentiate from other clinical conditions. The present approach in Bangladesh like much of South Asia is to diagnose arsenic cases is by external manifestation (melanosis and keratosis) in combination with a history of consuming of arsenic contaminated water. Within Bangladesh, the number of committed and trained health professionals need to be increased to improve detection of arsenicosis patients. The present data from Bangladesh makes quantifying the risk of acquiring disease from the number of people exposed is very difficult, as the data sets are often not fully compatible and health data have not been collected in non-standard ways. More surveys are needed to see the trend over time to support quantification of risk from arsenic to public health.

2.7 Arsenic in Agriculture

Agricultural crops, particularly high-yielding varieties of rice, vegetables and cereals are vulnerable to arsenic contamination from contaminated irrigation water. In Bangladesh, 95% of the groundwater abstracted is used for irrigation. There is no evidence that arsenic is essential for plant growth but it has phytotoxic effects on different crops and so may limit crop yields. In rice, the critical level in tops of the plant ranges from 20 to 100mg/l arsenic; and in roots 1000mg/l (Chino and Mitsui, 1967). Wetland rice is known to be very susceptible to arsenic toxicity as compared to upland rice, since As^{3+} would be more prevalent under reducing conditions (Maeta and Teshirogi, 1957).

In practice, ordinary crop plants do not accumulate enough arsenic to be toxic to humans; growth reductions and crop failure are likely to be the main consequences. It is likely that because of the soil/plant barrier effect, increased arsenic concentrations in soils will reduce crop production substantially before enhanced food chain accumulation occurs (Chaney, 1984). In contrast to several other potentially toxic elements, local health effects have been seen in areas naturally enriched with arsenic as well as areas contaminated by industrial activities, although it is not clear whether this results from exposure via the food chain (Havas *et al.*, 1987).

A number of initiatives have been taken in Bangladesh to measure the effects of arsenic contamination on irrigation water and subsequently in food crops. BRRI, BARI, BINA, BLRI, BSMRAU, BAU, FAO, CYMMIT have all been involved with these initiatives. FAO is finalizing a literature review on arsenic in agriculture with emphasis on Bangladesh, proving an overview of the current knowledge gaps and a strategy to address related issues.

There have been previous initiatives to investigate the risks to human health from exposure to arsenic from food. AusAid has supported research by the National University in Australia, although the findings have yet to be widely disseminated. Dhaka University have an ongoing study into arsenic accumulation in different plants and have made some preliminary estimates of human health risk. DGHS, NIPSOM and BSMMU have also initiated some work on assessing risks from some food-stuffs with support from WHO. UNICEF are funding Helen Keller International to reprocess existing food consumption data into a format suitable for a risk assessment to give insight in food consumption throughout Bangladesh including seasonal variation. This data can then be used in a rapid risk assessment of arsenic in the food chain, which balance the risks of arsenic with the need for essential nutrients and vitamins in crops.

CYMMIT, BRRI, BARI, BINA, BLRI, BSMRAU, BAU in cooperation with Texas A&M University and Cornell University (USAID funded) have been undertaking research on arsenic behaviour in the soil-plant system. They have made a start with developing a map with arsenic

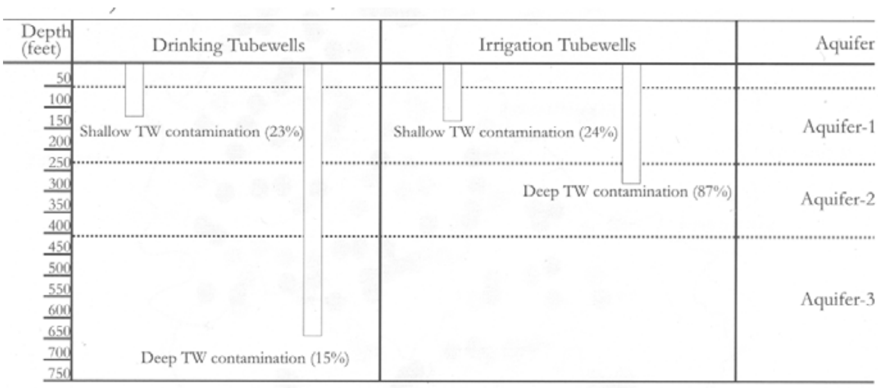


Figure 2.13: Arsenic contamination at different depths

soil concentrations in Bangladesh. Another valuable initiative is the start of a distance learning project to provide graduate students of BSMRAU an up-to-date course on all aspects related to arsenic in agriculture.

The University of Aberdeen in cooperation with the Bangladesh Agriculture University and Dhaka University has analysed rice from a number of countries, including Bangladesh, for arsenic speciation. Current activities also include arsenic speciation in some vegetables from Bangladesh with the results expected this year. BADC is performing a nationwide survey on irrigation water quality including arsenic.

Asia Arsenic Network has conducted a survey of irrigation wells in Sharsha Upazila of Jessore District. They reported that out of 331 irrigation wells (deep and shallow) 87% deep tubewells and 24% shallow tubewells had arsenic concentrations above Bangladesh drinking water standard. They also reported that the patterns of arsenic contamination in drinking and irrigation deep tubewells are almost same. The geological log is shown in Figure 2.13. However, the standard for drinking-water cannot be directly applied to irrigation water and more work is required to define a safe level of arsenic in irrigation water.

A number of research findings regarding the arsenic contamination of food crops were presented in an symposium organized by CYMMIT, Cornel University, Texas A&M University and USGS in January, 2005. In this symposium it was noted that agricultural soils in many areas of the country have been found to contain high levels of arsenic and that there was evidence of elevated arsenic accumulation in rice (Williams *et al.*, 2004). Little was known about the real or potential arsenic exposure of the rice-eating people of Bangladesh. Estimates showed about 50% of daily arsenic intake could come from rice grain when the intake of both water arsenic and rice arsenic was considered.

Findings from research into the effect of arsenic contaminated irrigation water on vegetables were also presented. The vegetables considered were potato, tomato, brinjal, okra, bitter gourd, chilli, cabbage, Indian spinach, amaranth, red amaranth, katua data, china shak and cauliflower. The arsenic content of these vegetables was found to be higher when irrigating with arsenic contaminated water than those grown with arsenic free water. The trend of arsenic accumulation in leafy vegetables is higher and lower in fruity vegetables and it was noted that arsenic uptake by different crop vegetables is variable (Ahmed *et al.*, 2003). The probability of significant amount of arsenic into the food chain has been reported in areas where the arsenic contaminated

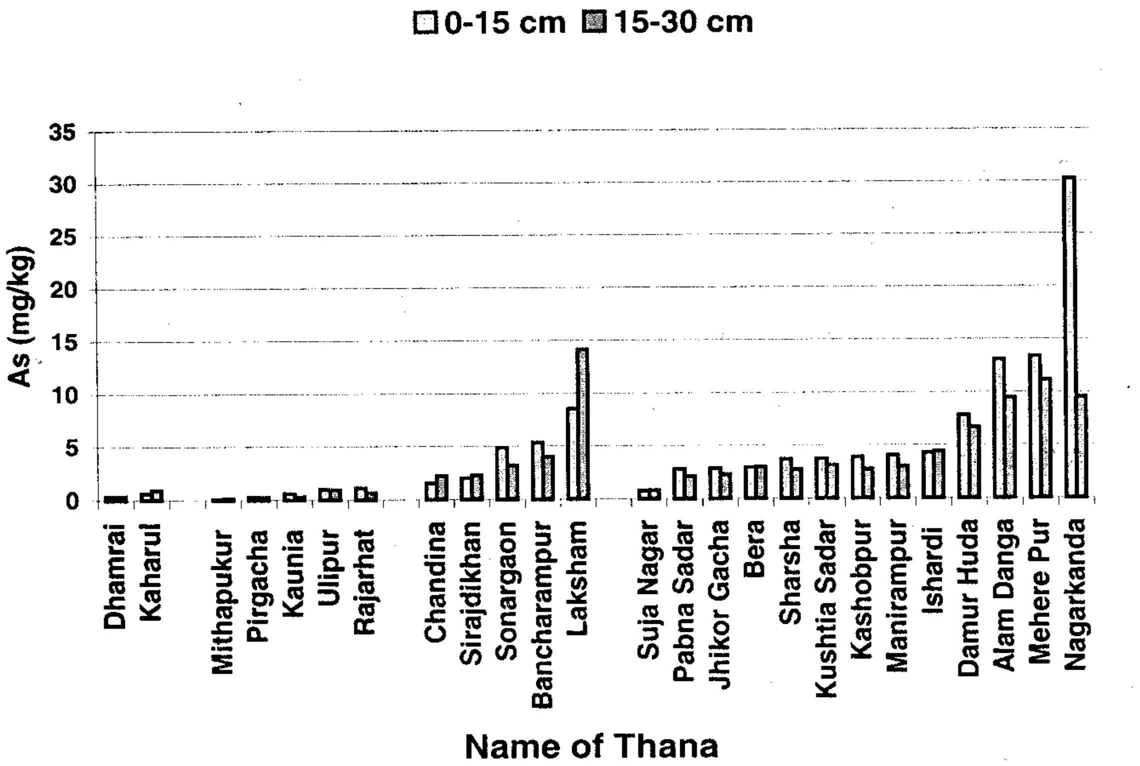


Figure 2.14: Concentration of arsenic in soil in soil at different depths of different Upazilas

ground water is used for irrigation (Ahmed, 2003). However, there remains insufficient evidence to determine the level of risk this poses, but is of concern as if a health risks is found in food, it implies that this maybe transported to non-arsenic affected areas through food.

2.8 Arsenic in Soil

A report of analysis of soil, pond water and tubewell water in the Satkhira, South-western coastal area of Bangladesh (Safiullah *et al.*, 2001) showed that the soil below 2.5 feet from the surface has high arsenic concentration (>400mg/l). Arsenic levels in uncontaminated, non-treated soils seldom exceed 10mg/l. Arsenic residues can accumulate to very high levels in agricultural areas where arsenic pesticides or defoliants were repeatedly used. It is apparent that agricultural uses can cause surface soil accumulation of 600mg/l or more (Walsh and Keeney, 1975). Arsenic can move downward with leaching water, especially in coarse-textured soil profile and in submerged soils (Stevens *et al.*, 1972). A study was conducted by taking soils of Gangatic alluvium floodplain, Testa alluvium flood plain, Meghna-Brahmaputra alluvium flood plain and Pleistocene Terrace soils from different districts of Bangladesh (Huq *et al.*, 2003). The result showed that in most of the cases arsenic content of top 0-5.9 ft is more than the bottom of 5.9-11.8 ft. The concentration of arsenic in soil at different depths of different Upazilas is shown in Fig. 2.15. The average concentration of arsenic in Bangladesh soil was 10 mg/kg and where the groundwater was uncontaminated the soil arsenic content is much below the average value. It was reported that there is no direct relationship with arsenic in groundwater and corresponding arsenic in soil but there was a tendency to build up accumulation in corresponding soil. The author also reported that there was a positive relationship of arsenic adsorption in soils and its clay content and pH on soil play a certain role in this regard.

The behaviour of arsenic in agricultural-production systems and the food chain is not yet well understood. There is an urgent need especially in Bangladesh, to determine what risks may be posed for crop production and to human health. Arsenic in irrigation-water interacts with the soils in a very complicated manner. The interactions are influenced by both water and soil properties, like pH, texture, mineralogy, organic carbon, redox potential, and reactions with free iron oxide, phosphorus and other chemicals. These water-soil interactions largely regulate the bio-availability of arsenic, e.g., its uptake and accumulation in edible plant parts.

Arsenic may also affect animals through feeding with high-As straw, which can be an additional potential indirect health hazard for humans. However, very little is known about this potential hazard in Bangladesh. There are critical knowledge gaps in the understanding of arsenic in crop-production systems. Continued research/education is needed for the development of arsenic management to ensure food security and safety.

There remains a need to develop a nationwide database on current arsenic levels in soils, assessment of impact of arsenic in irrigation water and soils, to understand which arsenic species predominate in plants and the bio-availability of arsenic in food and feed. This will help determine the safe levels of arsenic in irrigation water, soils and crops under the prevailing cropping systems of Bangladesh in terms of yield and crop quality. There is a need for further research in how crops and cultivators vary in their tolerance and uptake of arsenic and if there is significant variation, whether this can be used as a management tool.

3

MITIGATION INITIATIVES

3.1 Approach to Mitigation

The mitigation of arsenic requires interventions in screening, awareness-raising, water supply provision and patient identification and management. The only proven means to reduce the risks of arsenicosis is to reduce exposure to arsenic through the provision of water of acceptable levels of arsenic to be considered of low-risk.

Water supply interventions may be achieved through provision of alternative, arsenic ‘safe’ water sources or by removal of arsenic through treatment of the water. Arsenic removal has problems associated with social aspects, cost, operation and maintenance and there may be a risk of repeated contamination from sludge containing high level of arsenic. As a result, the primary focus of the mitigation effort in Bangladesh has been on the provision of alternative water sources.

3.1.1 Mitigation Initiatives

A significant number of projects and programmes have been implemented by different organizations across the country since the detection of the arsenic problem. The Department of Public Health Engineering have undertaken four major initiatives in water supply provision in arsenic affected areas, although only two are primarily arsenic mitigation. DPHE-Unicef and BAMWSP are both specifically designed for arsenic mitigation. DPHE-Danida and GOB IV are both general water supply programmes that have installed water supplies in arsenic affected Upazilas. When considering all stakeholders undertaking arsenic-related projects, 47 were water supply projects, 9 hydrogeology projects, 72 health projects and 4 agriculture projects. The distribution of arsenic related activity in different projects is shown in Figure 3.1. There is a further project focusing on the policy level. However, as noted further below, the arsenic-specific programmes have installed fewer water supplies than general water supply programmes working in arsenic affected areas.

Twenty-one projects have adopted an integrated approach to arsenic mitigation. Most projects took an integrated approach involving expertise in community mobilisation, water quality testing, safe water options, and identifying the patients while giving proper advice on safe water and nutrition as well as medical care. Universities in Bangladesh both national and private have also conducted some basic research regarding the arsenic problem, but dissemination has been generally poor. International Universities are also involved in different research work in collaboration with the local institutions.

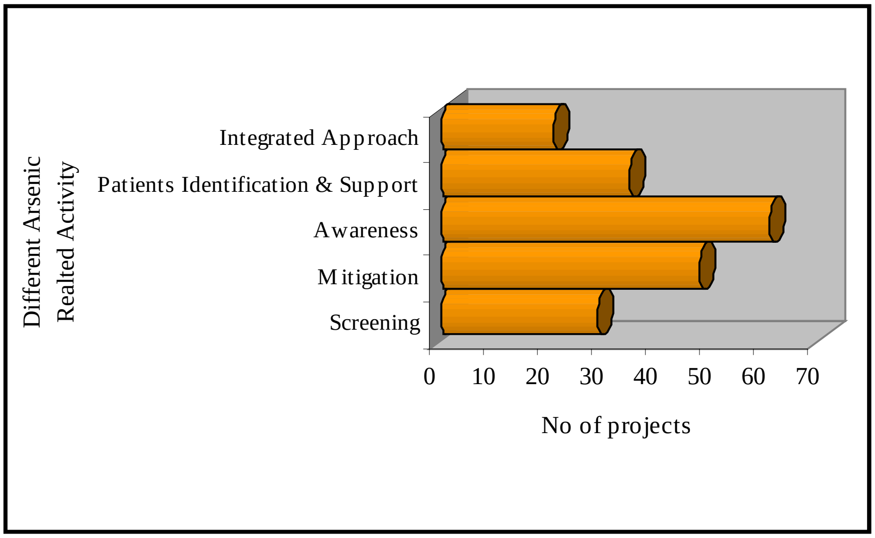


Figure 3.1: Year wise distribution of different water supply and arsenic related projects/programmes

Detailed information about the organizations and projects/programs is presented in Appendices A and C.

3.1.2 Alternative Water Options

A total of 18 organizations have piloted different mitigation activities in arsenic affected areas of the country through a total of 47 projects and programmes. The organizations involved in provision of water supplies include DPHE, AAN, BRAC, BRDB, BWDB, CARE, DAM, DASCOH, DCH, BAMWSP, EPRC, Grameen Bank, ICDDRB, IDE, ISDCM, MOH&FW, NGO Forum for DWSS, World Vision with support from the Government of Bangladesh and different development partners.

The development partners supporting these projects are AusAID, IDA, DANIDA, UNICEF, Harvard University, IDA, JICA, MISERIOR, NIEHS, SAVE THE CHILDREN USA, SDC, Sida, WHO, UNDP, Rotary Club, USAID. The organizations have worked with different alternative water supply options protected and unprotected dug wells, pond sand filters, river sand filters, arsenic iron removal plant and deep tubewells.

The Implementation Plan for Arsenic Mitigation in Bangladesh identifies a number of water supply technologies for use in arsenic mitigation: protected dug well, pond sand filter, rainwater harvesting, deep tubewell and river sand filters. It also notes the desirability of promoting piped water supplies.

Figure 3.2: Different types of installed dug wells

Dug wells

The dug well is the simplest technology of groundwater withdrawal. It has been used in many parts of Bangladesh before the introduction of shallow tubewell technology. Traditional dug wells used earthen pots are used to provide a lining and a bucket to withdraw the water. In an improved dug well, reinforced concrete is used and handpumps installed to make the dug well more acceptable to the community.

In areas like Madhupur and the Barind tract, where a thick and consolidated clay layer exists below the surface, dug wells are not feasible. The main difficulty with constructing a dug well is that they can be installed only in the dry season. Many dug wells once constructed experience a shortage of water during the dry season and they are vulnerable to microbiological contamination of water. Proper site selection for installation, sanitary protection, disinfection and cleaning of bottom silts, loose soils and sedimented iron settled in the dug well at least twice a year and careful monitoring can improve the water quality of the dug well. It is very difficult to find a proper site away from cowsheds, sanitary latrine and ditches in rural areas of Bangladesh. It some areas it has been reported that the dug well have high arsenic and manganese content (JICA/AAN, 2004; Ahmed *et al.*, 2005).

A significant number of dug wells have been installed in different arsenic contaminated areas of Bangladesh, with various modifications to the design, installation cost, O&M cost and user friendliness. However, in terms of operation and maintenance, cost and water quality dug well performs less well than the tubewell technology. Pictures of installed dug wells are presented in Figure 3.2.

Pond sand filters

Pond sand filters are the simplest technology of treating the surface water to make it drinkable/portable. Many of have been installed in the coastal belt of Bangladesh. Pond sand filters have been constructed in arsenic contaminated areas of Bangladesh.

Figure 3.3: Different types of installed PSF

The PSF is composed of a horizontal roughing filter filled with gravel and slow sand filter. Disinfection mechanisms have been developed by different organizations and has found to be effective, although there is less evidence of that chlorination technology can be transferred to communities. Pond sand filters have a number of drawbacks, including frequent microbial contamination, high initial cost of installation, high operation and maintenance and variable availability of perennial surface waters. Furthermore, it is often difficult to find a pond without fish-farming and other activities undertaken for income generation. Up to the 1960s dedicated ponds used only for the collection of drinking water were frequently found in the rural areas of Bangladesh and ownership of a pond was a prestige of the economically/politically powerful. Pond sand filters have been installed in different arsenic contaminated area of Bangladesh with different configurations, some examples are shown in Figure 3.3.

Rainwater

The people of the coastal belt of Bangladesh have been using the rainwater as the source of drinking water for long time. Globally, rainwater is used as a source of drinking water where the ground water is unavailable and surface water is highly polluted. Rainwater is abundant and free from iron, bacteria and other harmful material, although it can become rapidly contaminated in collection is not carried out properly and catchments maintained. Rainwater has a good potential for water supply in arsenic affected areas of Bangladesh.

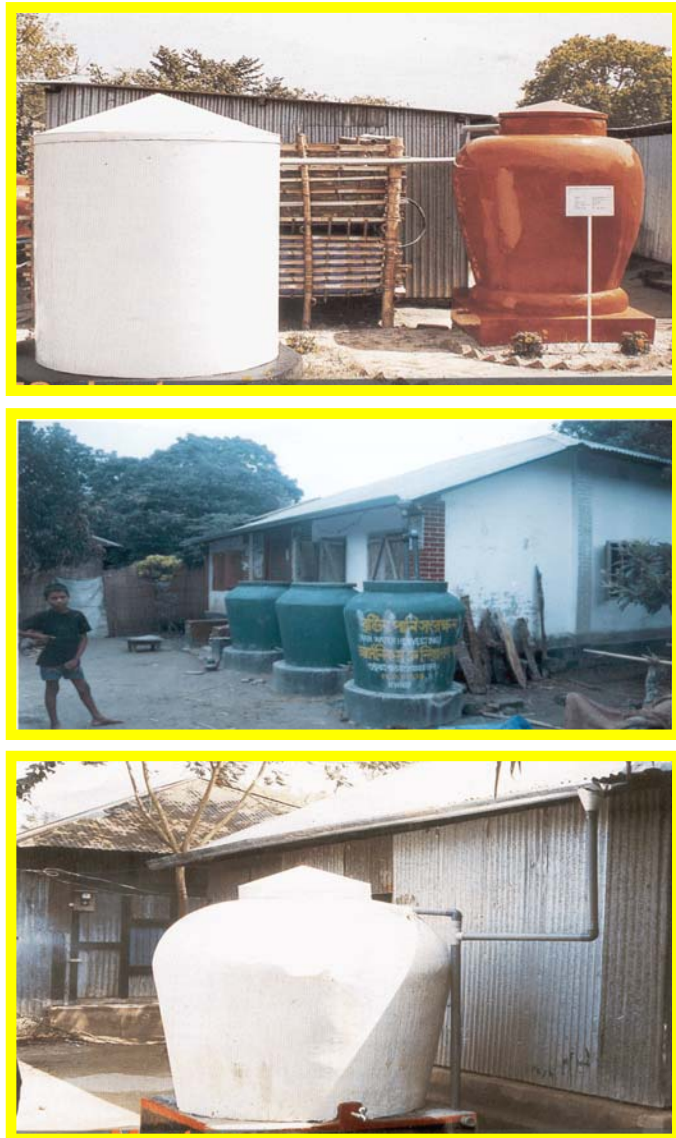


Figure 3.4: Different types of installed rainwater harvester

Rainwater harvesting systems consist of a catchment area and a reservoir. Different types of reservoir have been developed by different organizations with variable capacities from 1000 to 5000 litres and of different shapes. Larger underground reservoirs has have also been made for community and institutional water supply in rural areas. Generally, a house roof made of tin is used as the catchment area but modification of the catchment area is sometimes carried out using plastic sheets and polyethylene. Large numbers of household level rainwater harvesting units, such as those shown in Figure 3.4 has been installed, but standardization of catchment area and storage tank are needed in relation to rainfall intensity.

Deep tubewells

The Pleistocene aquifers in Bangladesh that are typically found at deeper levels have been found to be relatively free from arsenic contamination. The aquifers in Bangladesh are stratified and in most places the deeper aquifers are separated from contaminated shallow aquifers by relatively impermeable strata (aquicludes or aquitards). In a system of stratified aquifers, a tubewell that collects water from a deeper aquifer leaving one or more water bearing aquifers above is called a deep tubewell.

In Bangladesh two types of deep tubewells are installed, manually operated small diameter tubewells similar to shallow tubewells and large diameter power driven deep tubewells called production wells. Deep tubewells installed in those protected deeper aquifers where an aquiclude exists are producing arsenic safe water. In areas of Jessore and Sylhet where separating impermeable layers are absent and aquifers are formed by stratified layers of silt and medium sand, deep tubewells are likely show increased arsenic contamination over time due to the mixing of contaminated and uncontaminated waters. The possibility of contamination of the deep aquifer by inter-layer movement of a large quantity of groundwater is also possible.

Where the recharge of the deep aquifer is by infiltration through coarse media and replenishment by horizontal movement of water, the deep aquifer is likely to remain arsenic free even after prolonged water abstraction. The identification of areas having suitable deep aquifers and a clear understanding about the mechanism of recharge of these aquifers are needed to develop DTW based water supply systems in Bangladesh.

In most coastal areas, DTWs have been producing arsenic safe water for a long time and over 80,000 deep tubewells have been sunk in the coastal area. The Implementation Plans permits deep tubewells to be installed in coastal areas. In the other arsenic affected areas of Bangladesh, the presence of protected deep aquifers is not well recorded and installation of deep hand tubewells in these areas will require that implementing agencies follow the protocol for installation of arsenic safe tubewells in arsenic affected delta and flood plain areas of Bangladesh (GOB, 2004).

Sealing of the annular space around the tubewell has been emphasised in the protocol for installation of deep hand tubewells to protect the deeper aquifers from contamination (Figure 2.1). In soft unconsolidated clay, the boreholes are automatically sealed by overburden pressure of soil. The deep tubewells installed under GOB V program are being sealed by inserting mud balls prepared by a mixture of clay and bentonite into bore holes. Asia Arsenic Network used cement to seal the deep tubewells installed in arsenic affected areas. Proper sealing of boreholes at the level of impervious layer is a technological challenge. A standard practice in sealing the borehole at the level of impermeable layer is yet to be developed.

In general, permeability, specific storage capacity and specific yield of the aquifers usually increase with depth because of the increase in the size of aquifer materials. Experience in the design and installation of tubewells shows that reddish sand produces best quality water in respect of dissolved iron and arsenic. The reddish colour of sand is produced by oxidation of iron on sand grains to the ferric form. It will not release arsenic or iron in groundwater, rather ferric iron coated sand adsorbs arsenic from groundwater. For instance the Dhaka water supply is probably protected by its red coloured soil. Hence, installation of tubewell in reddish sand, if available, should be safe from arsenic contamination.

3.1.3 Microbial Contamination of Alternative Water Supplies

Pond sand filters and dug wells have significant risk of microbial contaminations and require modification to reduce microbial contamination (Howard, 2003). Further studies have shown that the risks associated with pathogens still outweighs those related to arsenic, and that dug wells and pond sand filters have an estimated disease burden several orders of magnitude higher than deep tubewells (Ahmed *et al.*, 2005). Rainwater also shows increasing microbial contamination in the dry season, but the health risks are less clear as the source of the microbes is not known. Deep tubewells show some increase in microbial contamination in the monsoon season, probably due to the use of contaminated priming water and there remain risks of arsenic contamination where deep tubewells are sunk in areas without a confining clay layer. However, where a confining layer exists and there is proper sanitary completion, deep tubewells have lower potential health risks than other options.

3.1.4 Arsenic Removal Technologies

Arsenic removal technologies have also been distributed in different parts of the country on a pilot scale. Some of the technologies are imported from outside the country and some are developed inside the country. Arsenic removal technologies introduced by different organizations in Bangladesh principally based on four different processes: oxidation/precipitation; co-precipitation and adsorption; sorption; and, membrane filtration. Most of those technologies were introduced in small and experimental scale. It is very important to consider several factors such as type of materials used in the system, availability of inputs, efficiency of arsenic removal, chemical and physical properties of the material, operating techniques and maintenance, replacement cost of materials, and environmental impact of the waste.

A rapid assessment of nine selected arsenic removal technologies was undertaken by WS Atkins with DFID funds in collaboration with BAMWSP and WaterAid in 2001. On the basis of that study the Technical Advisory Group (TAG) of BAMWSP recommended Alkan Enhanced Activated Alumina, BUET Activated Alumina, Sono-3-Kolshi Method and Stevens Institute of Technology for household level experimental use in arsenic affected areas. The Alkan Activated Alumina and BUET Activated Alumina Filter unit are principally based on activated alumina. The activated alumina has high surface area and high performance of arsenic removal but its de-sorption rate is very high and operates in a narrower range of pH, which raises the question of whether the material is environment friendly or it will create another problem of soil or water pollution. In the case of Sono-3-Kolshi, hydrated ferric oxide formed on the iron fillings has been suggested to be the arsenic- removing agent.

A list of different arsenic removal technologies used in Bangladesh is given in Table 3.1 (Ahmed *et al*, 2001). In 2000 the Government of Bangladesh established an environmental technology verification programme for arsenic mitigation (ETV-AM) with the assistance of CIDA. The BCSIR is the lead organization performing the verification of different arsenic mitigation technologies. Recently, they have conducted a verification programme on five technologies of which four technologies received provisional verification certification from BCSIR. These technologies were Alkan, Sono 3-Kolshi, Read F and SIDKO. A second phase for verification is being started in 2004 with a further 7-10 more technologies identified for long term monitoring and verification. Some details of the technologies are given Annex B.

Table 3.1: List of different arsenic removal technologies used in Bangladesh

<table>
<tr><th>Principles</th><th colspan="2">Technology</th></tr>
<tr><td rowspan="3">Oxidation/ Precipitation</td><td colspan="2">Passive Sedimentation</td></tr>
<tr><td colspan="2">In-situ Oxidation</td></tr>
<tr><td colspan="2">Solar Oxidation</td></tr>
<tr><td rowspan="5">Co-precipitation and Adsorption</td><td colspan="2">Bucket Treatment Unit</td></tr>
<tr><td colspan="2">Stevens Institute of Technology Unit</td></tr>
<tr><td colspan="2">BCSIR Filter Unit</td></tr>
<tr><td colspan="2">Fill and Draw Unit</td></tr>
<tr><td colspan="2">Chemical Packages</td></tr>
<tr><td rowspan="12">Sorptive Media</td><td rowspan="4">Activated Alumina Based</td><td>BUET Activated Alumina</td></tr>
<tr><td>Alkan Enhanced Activated Alumina</td></tr>
<tr><td>ARU of Project Earth Industries Inc. USA</td></tr>
<tr><td>Apyron Arsenic Treatment Unit</td></tr>
<tr><td rowspan="6">HFO based</td><td>Granular Ferric Hydroxide</td></tr>
<tr><td>Read-F Arsenic Removal Unit</td></tr>
<tr><td>Iron Coated Sand</td></tr>
<tr><td>Safi Filter</td></tr>
<tr><td>Sono-3-Kolshi Filter</td></tr>
<tr><td>Garnet Home-made Filter</td></tr>
<tr><td rowspan="2">Cartridge Filter</td><td>Chiyoda Arsenic Removal Unit, Japan</td></tr>
<tr><td>Coolmart Water Purifier, Korea</td></tr>
<tr><td>Ion Exchange</td><td colspan="2">Tetrahedron</td></tr>
<tr><td rowspan="2">Membrane Filtration</td><td colspan="2">MRT-1000 and Reid Systems Ltd.</td></tr>
<tr><td colspan="2">Low-pressure Nanofiltration and Reverse Osmosis</td></tr>
</table>

3.2 Number of Mitigation Options Installed

The blanket screening data show that there are 8,511 villages where tubewells have arsenic above 50µg/l (BAMWSP, 2004a). These are villages that fall under the emergency response phase according to the Implementation Plan for Arsenic Mitigation in Bangladesh. The total number of households in the emergency villages is 1,676,542. These villages are in 1236 different unions of 191 different Upazilas in 51 districts. The highest number of emergency villages exists in Chittagong Division and the lowest number is in Sylhet Division. Division wise statistics is presented in Table 3.2.

Table 3.2: Data on affected areas and population by Division

Division	*District*	*Upazila*	*Union*	*Villages*	*Household*	*Population*	*Patients*
Dhaka	17	65	405	2587	439422	2396057	2331
Barisal	3	13	79	346	90295	520732	323
Chittagong	7	36	400	3943	819996	5646034	7268
Rajshahi	10	17	49	113	22765	119996	965
Khulna	10	46	243	1354	283674	1288351	1923
Sylhet	4	14	60	197	20390	120819	43
Total	51	191	1236	8540	1676542	10091989	12853

Source: NAMIC/BAMWSP

The information regarding the number of mitigation options were collected from approximately 120 different projects/programmes/pilot projects implemented by different organizations in different contaminated areas. Not all these projects are specifically arsenic mitigation, but are general water supply improvements projects. The mitigation options installed include dug wells, rainwater harvesting (primarily for households but also some community units), deep tubewells, pond sand filters, arsenic iron removal plants, shallow shrouded tubewells, deep-set pumps, piped water supplies, community based arsenic mitigation technologies and different types of household level arsenic removal technologies. The installation of mitigation options is a continuous process, many projects will continue for the next 5 years.

In general, the recording of mitigation option installation by programmes has not been as good as should have been and improving record keeping is an important need for the sector. Of greatest concern is that in a large number of cases it is not possible to identify the village in which mitigation options have been installed. Furthermore, different organisations have kept data to differing levels of detail, thus for BAMWSP, DPHE-UNICEF, DPHE-DANIDA, Asia Arsenic Network (AAN) and Bangladesh Rural Development Board (BRDB) are available to village level, permitting comparison to meeting the objectives of the emergency phase response. The major problem is that the GOB IV data is not available to village level, but only goes to Union level for some years, Upazila level for other years and District level only for at least two years. World Vision data is only available at the Upazila level and there appears to be no prospect of other data becoming available. In addition, some other more minor programmes, such as Dhaka Community Hospital (DCH), International Development Enterprises (IDE) and BRAC for which no village level data is currently available. An overview of the mitigation options installed as of July 2005 is given in Table 3.3, with the contributions of different stakeholders identified.

Table 3.3: Options installed by stakeholder and technology

STAKEHOLDER	*DW*	*PSF*	*RWH*	*DTW*	*AIRP*	*PWSS*	*SST*	*DSP*	*Total*
Asia Arsenic Network (AAN)	38	13	0	9	0	1	2	0	63
BAMWSP	739	12	3,001	1,867	0	0	0	0	5,619
Bangladesh Rural Development Board (BRDB)	227	0	95	14	0	0	0	0	336
Dhaka Community Hospital (DCH)	81	5	11	0	0	15	0	0	112
DPHE-UNICEF	1,552	321	7472	403	0	4	205	0	9,957
International Development Enterprise (IDE)	268	0	804	0	0	0	0	0	1,072
NGO Forum	241	47	384	85	702	4	0	23	1,486
World Vision	106	490	1,205	0	353	0	0	0	2,154
Others	29	23	147	7	0	0	0	0	206
Arsenic mitigation programmes	3,281	911	13,119	2,385	1,055	24	207	23	21,005
DPHE-DANIDA	2	20	132	14,706	2	9	0	0	14,871
GOBIV	2,985	2,590	73	57,718	2,714	0	4,873	110	71,063
All Programmes	6,268	3,521	13,324	74,809	3,771	33	5,080	133	106,939

The single largest provider of water supplies in arsenic affected areas if the GOB IV project, which uses only GOB funds. This, however, is a general water supply programme and not an arsenic mitigation programme and therefore many of these water supplies will not necessarily been targeted on those communities exposed to the greatest risk from arsenic. The same is largely true for the DPHE-DANIDA programme, although this does have a specific arsenic mitigation component.

Deep tubewells have been the principal water supplies installed in arsenic affected Upazilas, primarily through GOB IV and DPHE-DANIDA. Rainwater harvesting unit have been the next most commonly installed units. The arsenic mitigation programmes have installed over 21,000 alternative water supplies, with DPHE-UNICEF being the largest programme. In arsenic mitigation programmes, rainwater harvesting have been the most commonly installed options, with dug wells the 2nd most common. The use of deep tubewells has been more limited in these programmes largely because of restrictions enforced on the use of deep tubewells. Figure 3.5 below shows the breakdown of mitigation options by technology type.

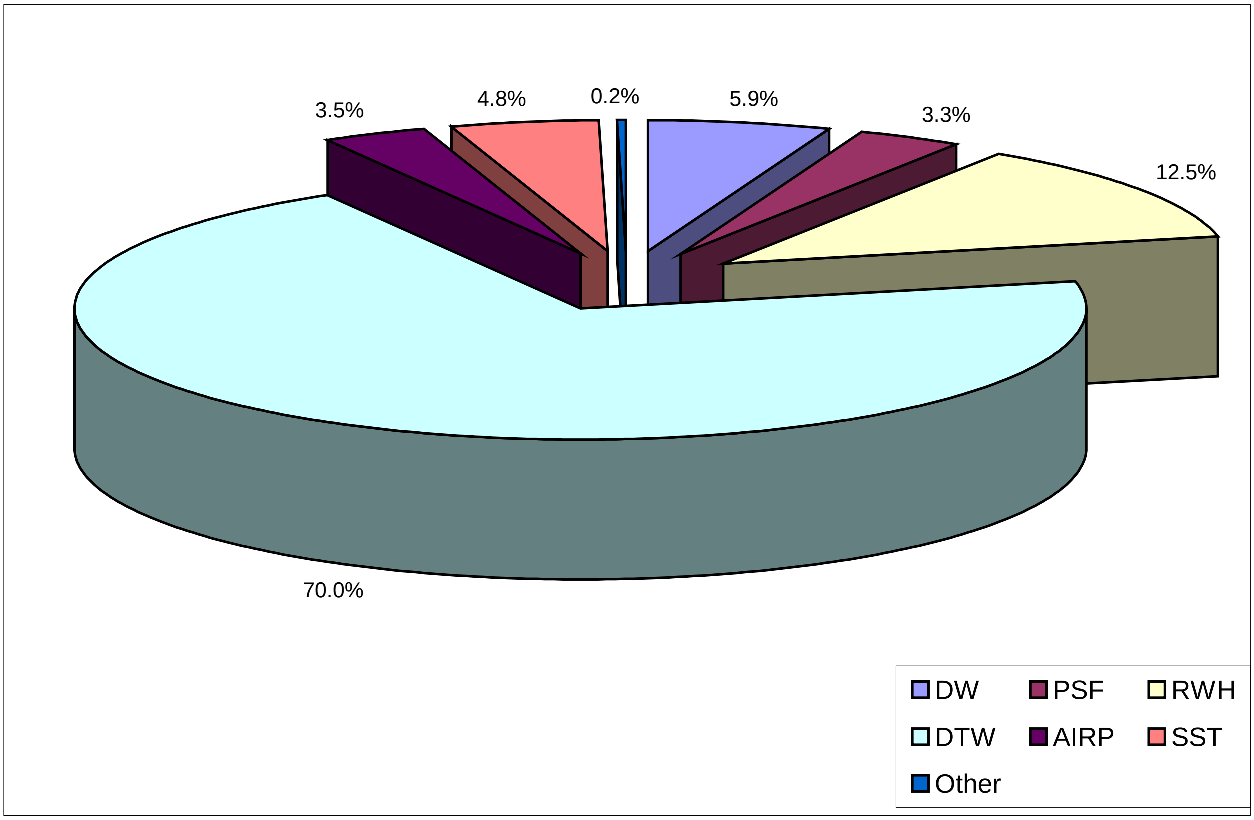


Figure 3.5: Breakdown of options by technology type in arsenic affected Upazilas

The data in table 3.3 show that almost 107,000 alternative water supplies have been installed in arsenic affected areas. If the expected usage of 50 households per option noted in the emergency phase is used for all options except AIRP (for which 10 is realistic) and rainwater harvesting (which are assumed to be for an individual household), the current options should be sufficient to serve 4,546,532 households or 38% of the total households in arsenic affected areas.

The provision of mitigation options by level of contamination is shown in Figure 3.6 below. This shows that for the supplies where full data are available, the highest proportion of water supplies have been installed in areas with less than 40% of tubewells contaminated, followed by those with 40-80% contaminated and the areas with over 80% tubewells contaminated. The water supplies in the areas with less than 40% tubewells contaminated have primarily been installed in general water supply programmes, which would account for the larger number.

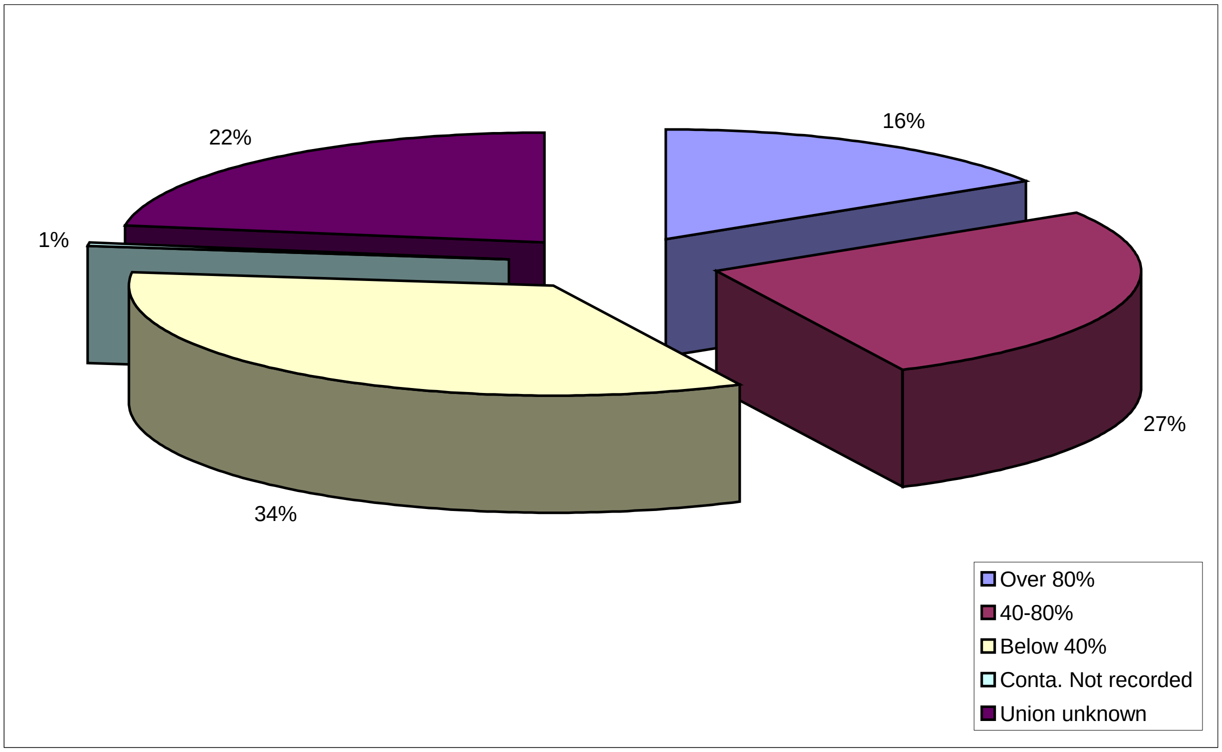


Figure 3.6: Proportion of mitigation options installed by level of contamination

The data on mitigation option should be kept in the context of the relative populations, the areas with less than 40% tubewells contaminated represent 68.9% of the population of all areas that are arsenic contaminated, compared to 20.4% for the 40-80% tubewells contaminated group and only 10.7% for the above 80% tubewell contaminated group. Nonetheless, the data indicates that the worst arsenic affected areas have not had sufficient priority to date.

3.0 Union level analysis

The data available at Union level (BAMWSP, DPHE-UNICEF, DPHE-DANIDA, AAN, BRDB, NGOF and some GOB IV) was analysed. In this data there are 17,540 alternative water supplies that could be considered to be arsenic mitigation options that have been installed in Unions with over 80% of tubewells arsenic contaminated.

Based on the recommendations in the Implementation Plan, this should be sufficient to cover 1,299,397 households (based on 50 households per option except for rainwater which is assumed to serve a single household and AIRP that serve 10 families). This represents 47% of the households recorded in the Unions with over 80% tubewells contaminated where data is available on the number of households. There is therefore a continuing shortfall of 53% of households exposed.

Data on villages where options have been installed are only available for some of the programmes (BAMWSP, DPHE-UNICEF, DPHE-DANIDA, AAN and BRDB). These programmes have together installed 12,168 alternative water supplies in villages with over 80% of tubewells contaminated, of which 5,310 are rainwater harvesting units and 15 are AIRPs. Using 50 households per alternative water source, one household for rainwater harvesting, and 10 households per AIRP, the installed options can serve a total of 347,610 households. A total of 2,133 villages were covered by these programmes and within the villages covered, the options installed are sufficient to meet the needs of 86% of the households in the village based on the requirements of the Implementation Plan. It should be noted that if GOBIV data is included, then this figure would increase significantly.

In the data set with Union level data, a further 27,779 alternative water sources have been installed in Unions with 40-80% of all tubewells contaminated. These villages have been classified as medium-term response villages, where only 20 families per source is considered appropriate. The water supplies installed to date would be sufficient to serve 427,047 households, which is 30% of the total living in Unions with 40-80% contamination.

A further 34,009 alternative water supplies have been installed in Unions with less than 40% tubewells contaminated, mostly installed by GOB IV. A figure of 20 households per option is considered appropriate and the supplies installed represent further 680,180 households being covered. This is equivalent to 11% of the households living in these Unions. However, whether arsenic mitigation is required in these Unions is debatable as other approaches such as well-sharing would be feasible thus the population with access to arsenic-safe water will be much higher.

3.3. Awareness Campaigns

Awareness campaigns about arsenic can reduce the risk of many arsenic-related problems. Different types of awareness campaign have been conducted in Bangladesh since 1995. A variety of materials developed by different organisations have been used in awareness campaigns. The IEC materials included posters, banners, leaflets, stickers, flip charts, and TV and Radio messages and serials performed in different media. In addition village meetings, courtyard meetings, imam orientation, school awareness programmes were conducted. Although the detail of the messages varied, in general terms the key messages provided through the campaigns were:

Figure 3.7: Photograph of awareness campaign regarding arsenic

- What arsenic is and its source;
- The consequences of drinking arsenic contaminated water for long time;
- The alternative sources of arsenic free safe water;
- How the alternative source of arsenic free safe water option is maintained; and
- How arsenic affected individuals can be identified and how they can get help.

Officials of different levels of the governmental and non governmental organizations both at local and national levels received training on different issues of arsenic problem and its remedy; from identification of arsenic contaminated tubewell to patient identification and management in different arsenic contaminated areas of the country. A photograph of awareness campaign is presented in Figure 3.7.

Twenty five organizations were engaged in awareness-raising in different parts of the arsenic contaminated areas at local and national levels working through a total of 60 projects and programmes. Different departments of the government and national and international NGOs supported the awareness campaign including AAN, ARBAN, ASD, BRAC, BRDB, CARE, DAM, DCH, DPHE, DSK, EPRC, Grameen Bank, Green Hill, ICDDRB, IDE, ISDCM, LGED, MOH&FW, NGO Forum for DWSS, Phulki, PIB, Society for Urban Health, UST, VERC, World Vision. Development partners have provided support to such activities through funding and technical assistance. Some overlapping of awareness campaign has been observed in different areas. The working areas of some organisations involved in the awareness campaign are presented in Table 3.5.

BAMWSP conducted an assessment on the awareness-raising campaign in 147 Upazilas of Bangladesh. The report (BAMWSP, 2004b) found that 91% of the people understood the meaning of the red and green marked tubewells and thus that there was good knowledge about arsenic. The survey also showed that the knowledge about the symptoms of arsenic related disease among rural people is inadequate and only 59.9% respondents know that nutritious food is required to contain the deteriorating effect of arsenic related disease.

The DPHE-UNICEF project found that ongoing awareness-campaigns had had a significant positive impact on the knowledge of communities affected by arsenic and that in particular the poor had shown a particular improvement in knowledge as a result (Rosenboom, 2004). Attitudes also seen to have changed with a more positive attitude towards arsenicosis sufferers being noted. However, practices seemed to have less influenced by the awareness-campaign, but the response rate was very low.

Table 3.5: Working area of some organization conducted awareness campaign on arsenic and health issues

Organization	Working Area
AAN	Uz: Sharsha
BRAC	Uz: Bhanga, Monirampur, Haimchar, Barura, Matlab, Sonargaon, Jichargacha, Faridpur Sadar, Nagarkanda, Rajoir, Nikli, Itna
CARE	Dist: Sitakunda, Netrokona, Kishoreganj, Sunamganj, Kurigram, Gaibandha, Sirajganj, Dinakpur, Jessore, Mymenshingh, Gazipur
DANIDA/DAM	Uz: Bakerganj, Barishal Sadar, Pirojpur Sadar, Sonagazi, Laxmipur Sadar, Rangamati, Begumganj, Noakhali Sadar
DCH	All upazilas of Bangladesh, 4 Districts and 11 Upazilas, 14 Upazilas, 25 areas of 21 upazilas, 30 Villages of Bangladesh, All the districts of Bangladesh, Serajdikhan Bera Laksham, 31 Upazilas, 1600 cases in rural and urban areas Serajdikhan: 2 villages
BAMWSP/DPHE	All over Bangladesh
EPRC	Uz: Kalia
Grameen Bank	Uz: Kochua
ICDDRB	Uz: Matlab
IDE	Uz: Sariakandi, Chapai Nawabganj, Gomastapur, Nachole, Shibganj, Bagha, Baghmara, Boalia, Charghat, Durgapur, Godagari, Mohanpur, Paba, Puthia, Tanore, 4 villages of Narayanganj and Kochua uz
LGED	Dist: Bagerhat, Barisal, Brahmnbaria, Chandpur, Chapainawabganj, Comilla, Faridpur, Gaibandha, Gopalganj, Jamalpur, Jessore, Jhenaidaha, Madaripur, Magura, Munshiganj, Natore, Noakhali, Rajbari, Ramgati, Sirajganj, Tangail, Thakurgaon pourashava area
MOH&FW	2000 selected villages upazila is not mentioned
NGO Forum for DWSS	Uz: Ghior, Bakshiganj, Lalpur Baghatipara, Nasirnagar, Jhenaidaha Sadar, Bagha, Charghat, Babuganj, Nabinagar, Barura, Sirajdikhan, Damurhuda, Manirumpur, Bhanga, Shibchar Upazilas
BRDB	Uz: Faridpur Sadar, Bhanga, Nagarkanda, Rajoir
DPHE/UNICEF	Uz: Jhikorgacha, Sonargaon, Haim Char, Barura, Bhanga, Manirampur, Itna, Nikli, Nabinagar, Mirzapur, Bera, Serajdikhan, Muktagacha, Jessore Sadar, Kalia, Guiripur, Nandail, Kachua, Shahrasti, Muradnagar, Rajoir, Shib Char, Saturia, Bashail, Bancharampur, Damurhuda, Homna, Manikganj Sadar, Babuganj, Bakshigonj, Ghior, Nakla, Astogram, Jamalpur Sadar, Mymensingh, Tangail Sadar, Sherpur Sadar, Borolekha, Kaligonj, Dhamrai, Keranigonj, Munshigonj Sadar, Monohardi, Palash, Shibpur

A risk assessment of arsenic mitigation options supported by APSU included a social acceptability survey, which asked questions about the knowledge of communities about arsenic. This study found while people were aware of arsenic and the need not to use red tubewells for drinking and cooking, very small numbers of people knew that arsenicosisis not contagious, that arsenic is a poison that gradually affects health or that water from red tubewells could still be used for other purposes (Ahmed *et al.*, 2004). Similar findings were obtained in a study by the Asian Development Bank in rural areas and in evaluations in District Towns (Hanchett, 2004).

The different studies all appear to show that knowledge about arsenic has greatly increased because of the awareness-campaigns and that attitudes have improved. However, most studies point to limited knowledge on more complex matters related to arsenic and that knowledge is not directly translating into improved practice.

3.4 Patient Identification and Treatment

Arsenic accumulation in the body typically occurs for a long period of time before symptoms are seen and the shortest latency period currently accepted is 9 years. A photograph of arsenic effected women is shown in Fig 3.8. It is thought that it takes up to 20 years for cancer symptoms to develop (Ahmed and Ahmed, 2002). The symptoms of arsenocosis are very difficult to differentiate from other clinical conditions. Different survey results showed that the prevalence of arsenicosis in the country is very low but rate of increase of the number of patients must be taken into consideration for making any strong comments.

A total number of 13 organizations have been involved in patient identification, these are AAN, BRAC, BRDB, CARE, DAM, DCH, DGHS, ICDDRB, IDE, ISDCM, NGO Forum for DWSS, NIPSOM, World Vision in different areas of the country. A number of development partners provided funding, particularly BAMWSP, WHO and Unicef.

After screening for patient identification by different organizations BAMWSP prepared a map of identified patient located in different areas of the county, presented in Figure 3.8 (BAMWSP, 2004a). The Unions where the number of patients exceeds 100 per 10,000 population are presented in Table 3.6. A total number 38,118 patients have been identified in different areas of the country out of which 46% is male and 54% is female. The higher number of females compared to males is different to the findings from other studies, where more men than women have typically be found. Patient identification has not always been carried out by doctors, but by a range of health staff. Preliminary identification of patients should be confirmed through examination of doctors to avoid misdiagnosis. It is now important to generate the time series data to see the trend of arsenic contamination on human life and the recovery rate.

Table 3.6: Unions where the number of patients exceeds 100 per 10,000 population

District	*Upazila*	*Union*	*No of Patient*	*District*	*Upazila*	*Union*	*No of Patient*
Chandpur	Hajiganj	Hatila	321	***Kushtia***	Daulatpur	Prayagpur	303
Chuadanga	Alamdanga	Baradi	100	***Lakshmipur***	Raipur	Char Bangshi	404
Chuadanga	Alamdanga	Nagdah	115	***Lakshmipur***	Ramganj	Chandipur	160
Chuadanga	Chuadanga	Begumpur	107	***Lakshmipur***	Ramganj	Darbeshpur	162
Comilla	Laksam	Gobindapur	129	***Lakshmipur***	Ramganj	Ichhapur	109
Comilla	Laksam	Hasnabad	272	***Lakshmipur***	Ramganj	Lamchar	143
Comilla	Laksam	Natherpetua	153	***Madaripur***	Madaripur	Kendua	101
Comilla	Laksam	Paschim Gaon	284	***Meherpur***	Meherpur	Amjhupi	186
Comilla	Laksam	Uttar Jhalam	260	***Meherpur***	Mojibnagar	Bagoan	184
Comilla	Nangalkot	Adra	224	***Munshigonj***	Tongibari	Panchgaon	102
Comilla	Nangalkot	Nangalkot	412	***Narsingdi***	Belabo	Binyabaid	145
Gopalgonj	Gopalganj Sadar	Paikkandi	117	***Nawabganj***	Nawabganj Sadar	Ranihati	185
Gopalgonj	Tungipara	Patgati	103	***Noakhali***	Senbagh	Arjuntala	115
Jessore	Chowgachha	Jagadishpur	133	***Noakhali***	Senbagh	Chhatarpaia	603
Jessore	Keshabpur	Panjia	182	***Noakhali***	Senbagh	Kesharpar	125
Khulna	Dighalia	Senhati	167	***Pabna***	Sujanagar	Ahammedpu r	146
Kishoreganj	Bhairab	Sadakpur	101	***Rajbari***	Pangsha	Jashai	182
Kishoreganj	Bhairab	Shibpur	167	***Satkhira***	Assasuni	Kulla	119
Kushtia	Bheramara	Dharampur	122	***Satkhira***	Kalaroa	Joynagar	103
Sunamganj	Dowara Bazar	Uttar D. bazar	193	***Satkhira***	Tala	Khesra	102
				Sirajganj	Raiganj	Dhubil	128

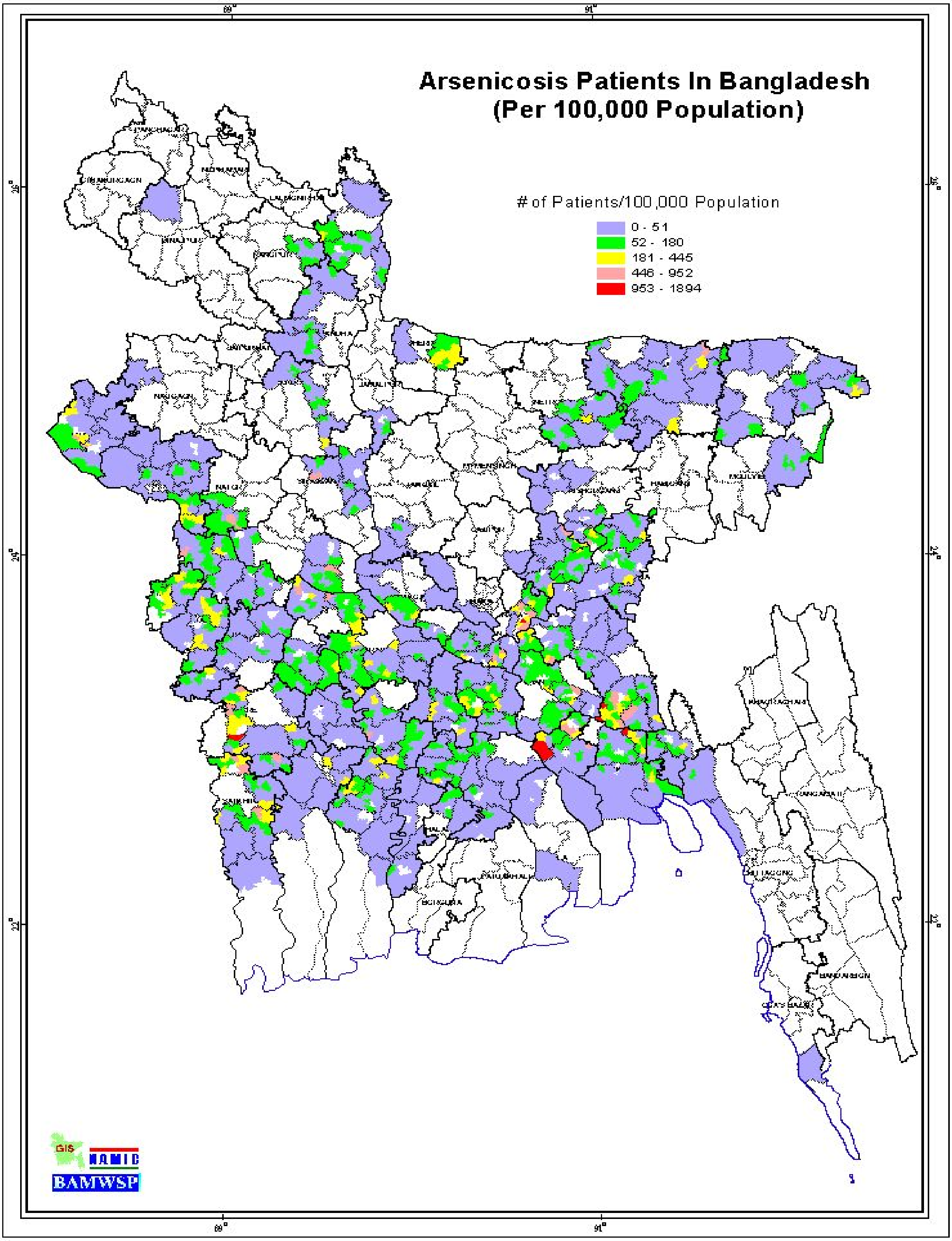


Figure 3.8: The distribution of arsenic patients in different areas water of Bangladesh. Courtesy BAMWSP, 2004

Various research projects have been conducted regarding the treatment of arsenicosis patients. One study showed that spirulina can reduce the arsenic content of liver, spleen, kidney, heart and lung (Haq *et al*., 2000). Another study showed that antioxidants (vitamins and minerals) were useful and safe therapeutic agents, which could increase arsenic excretion through urine, hair and nail in adult patients with chronic arsenic poisoning (BACS, 2003). Topical use of salicylic acid (10-20%) has been found effective in reducing the pain and roughness of keratosis. Improvement of nutritional status by adequate protein intake was likely to enhance the effects of antioxidants (BACS, 2003).

The Government of Bangladesh has designed and approved a protocol for case identification and case management for arsenicosis based on a regionally accepted protocol developed by WHO (GOB, 2004). Emphasis has been given to develop trained manpower for case identification by giving training to the health manpower at different levels, health workers, doctors, developing suitable material for case identification and management. The flow diagram of diagnosis of arsenicosis is presented in Figure 3.9 and case management protocol is given in Table 3.7.

Table 3.7: Protocol for case management for arsenicosis cases

Primary Health Services e.g. PHC	*Secondary Health Care Services e.g. UHC and/or District Hospital*	*Tertiary Health Services e.g. State Hospital*
• History of physical examination for detection of suspected cases of arsenocosis • Counseling to terminate consumption of arsenic contaminated water and provision of information on arsenic safe water supplies for patients for melanosis • Provision of supportive care by topical keratolytic agents for patients with keratosis. Presently 5-10% salicylic acid and 10-20% urea • Periodic surveillance of skin cancer • Patients and community education: Counseling for social problem • Advice concerning adequate nutrition • Arrangement for rehabilitation services • Refer to higher level if indicated	• Detailed exposure history and biological monitoring (as needed) of suspected cases referred from primary care providers • Confirmatory physical examination for dermal lesion and systemic disorders • Management of skin cancer and uncomplicated systemic disorders • Provision for rehabilitation services • Record keeping and public health reporting regarding confirmed cases	• Reiteration of secondary health services. • Management of invasion or metastasis skin cancer and internal cancer by surgery, radiotherapy and Chemotherapy • Management of major systemic complications and disorders • Provision for rehabilitation services • Research regarding therapeutic regiments

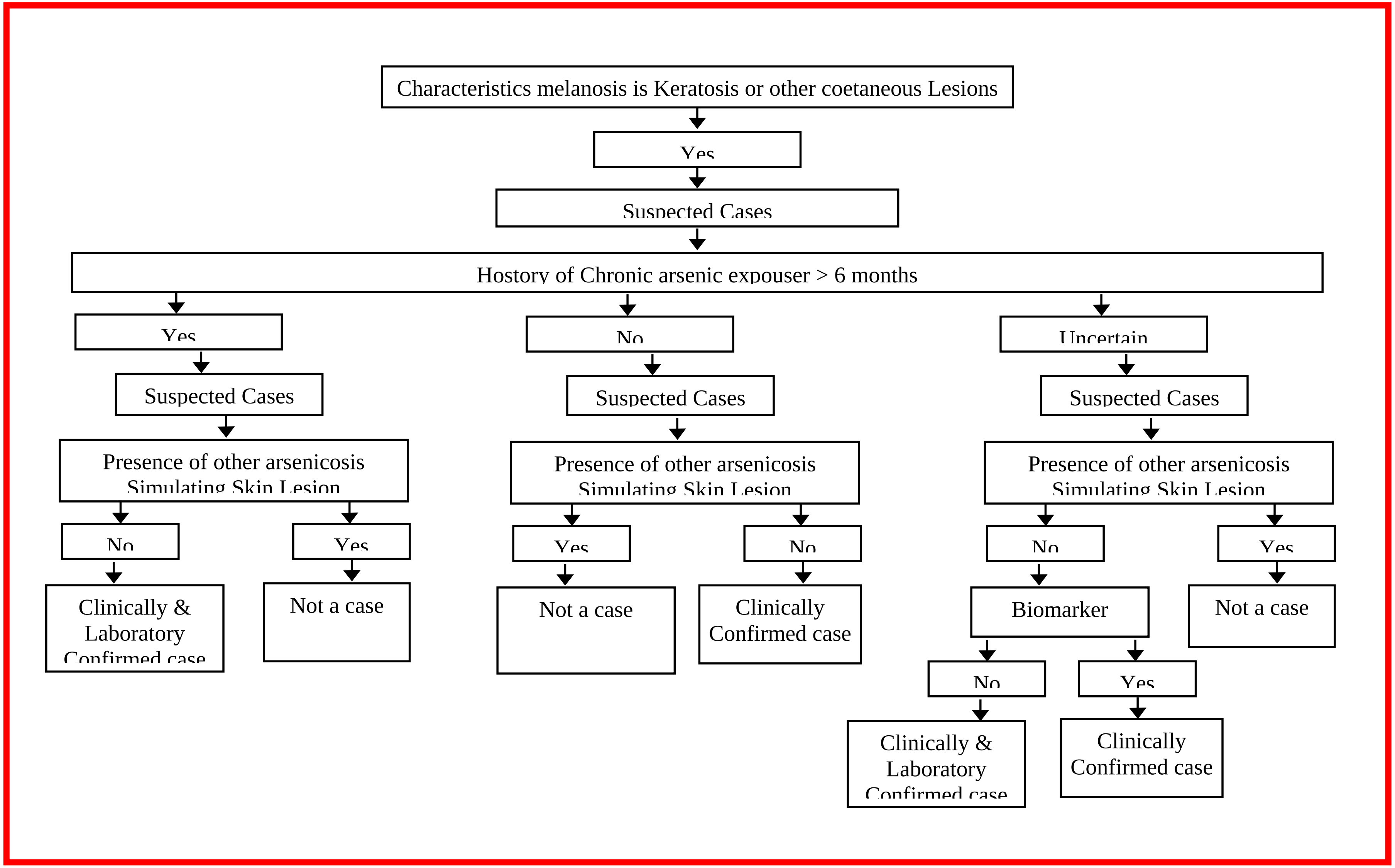


Figure 3.9: Flow Diagram for Diagnosis of Arsenicosis

3.5 Future Plans for Arsenic Mitigation of Different Organizations

Every organization working with arsenic related problems was asked for their future initiatives. Some of the organizations provided their future programmes. The programmes are summarized in Table 3.8 in alphabetical order.

Table 3.8: Proposed projects and programmes

Which related area would cover? *(Put ✓ mark)*			☑ Water Supply ☑Water resources Aspects ☑ Arsenic Removal Technologies ☑ Agricultural Aspects ☑ Hydrogeology ☑ Health Aspects ☑ Research			
No.	**Name of the Organization**	**Name of the Project/Program**	**Tentative Duration (Year)**	**Project Location**	**Targets**	**Beneficiaries**
1	**AAN**	Sustainable mitigation of Arsenic Contamination under the integrated local government system.	3	Sharsha and Gowcaha upazilas Jessore District		2.5 million People
2	**BRAC**	BRAC is in the process of implementing several rural piped water projects in different areas	0.5	Not yet decided	Whole village	Avg 500 families in each village
3	**BRAC**	Targeting Low-Arsenic Aquifers for Community and Private Wells in Bangladesh: An Intervention to Reduce Arsenic Exposure Throughout Araihazar Upazila	2	Araihazar	Whole upazila	Arsenic exposed villagers
4	**BWDB**	Detailed Hydrogeological Studies with Exploration of Deep Aquifers in Deltaic and Flood Plain Areas	5	Deltaic and Flood Plain Area of Bangladesh	37 districts and 175 upazila	Observation will be used by the community people after research
5	**CYMMIT**	Project: <u>Impact of arsenic contamination on agricultural sustainability and food quality</u> Program : Development of a nationwide database on arsenic in irrigation water, soils and crops	5	To cover all thanas of all districts	Water, soils, crops under varied agro-ecological zones	Farmers, arsenic researchers, policy makers
6	**CYMMIT**	Program: Study of the effect of high-As feed (e.g. rice straw) on cattle health	5	To be identified	Cattle in high-As areas	Farmers, livestock enterprises
7	**CYMMIT**	Program: Distant learning for Bangladeshi students through courses offered by Cornell University and Texas A&M University	5	BSMRAU	Graduate students	Bangladeshi students and arsenic researchers

Which related area would cover? *(Put ✓ mark)*			☑ Water Supply ☑Water resources Aspects ☑ Arsenic Removal Technologies ☑ Agricultural Aspects ☑ Hydrogeology ☑ Health Aspects ☑ Research			
No.	**Name of the Organization**	**Name of the Project/Program**	**Tentative Duration (Year)**	**Project Location**	**Targets**	**Beneficiaries**
8	**CYMMIT**	Development of arsenic mitigation technology for irrigation water, soils and crops	5	Selected command areas in different arsenic hot spots	Reducing the As load on soils and crops	Farmers
9	**ICDDRB**	Chemo Prevention of arsenic Induced Skin Cancer	2005-2012	Matlab Laksham Arihazar Sonargaon	Safe Water supply Options, Tube well screening, Patients Identification, Awareness Campaign	n = 4400 Patients
10	**ICDDRB**	Arsenic and Child Respiratory Health	2005-2009	Matlab	Safe Water supply Options, Tube well screening, Patients Identification, Awareness Campaign	Siblings of Patients
11	**ICDDRB**	Arsenic and Child Development	2003-2007	Matlab	Safe Water supply Options, Tube well screening, Patients Identification, Awareness Campaign	Exposure = 2000
12	**JICA**	Strengthening of Water Examination System in Bangladesh	1 year (Mar 2005 to Mar 2006)	Dhaka, Noakali, Jhenidah	To establish water quality testing system in DPHE	DPHE
13	**JICA**	Technical Assistance for Strengthening of Water Examination System in Bangladesh	3 years (Jan 2006 to Dec 2008)	Dhaka, Noakali, Jhenidah	To establish water quality testing system in DPHE	DPHE
14	**JICA**	Technical Assistance for Sustainable Arsenic Mitigation in Jessore District	3 years (June 2005 to May 2008)	Jessore District	To establish sustainable arsenic mitigation system and to implement sustainable arsenic mitigation activities in Jessore district	Directly, residents who live in highly arsenic affected area in Jessore district. Indirectly, 2.5 million people in Jessore district by establishment of sustainable arsenic mitigation system
15	**BAMWSP DPHE**	Construction of piped water supply system			300 villages	Rural communities in arsenic affected Upazilas
16	**BAMWSP DPHE**	Point source water supply system		15 upazilas	3700 nos	Rural communities in arsenic affected Upazilas
17	**BAMWSP DPHE**	Supply of instrument to BCSIR			LS	

Which related area would cover? *(Put ✓ mark)*			☑ Water Supply ☑Water resources Aspects ☑ Arsenic Removal Technologies ☑ Agricultural Aspects ☑ Hydrogeology ☑ Health Aspects ☑ Research			
No.	**Name of the Organization**	**Name of the Project/Program**	**Tentative Duration (Year)**	**Project Location**	**Targets**	**Beneficiaries**
18	**DPHE/DANIDA**	Water supply and Sanitation Transition Component	5	Same districts as now but including additional 147 unions.	Not finalized	Not finalized
19	**DPHE/Unicef**	Rural Hygiene, Sanitation and Water Supply Project (DFID funded)	5 year implementat ion phase	Covers 47 Districts	Not finalized	Not finalized
20	**GUP**	Arsenic Mitigation Project	3	Rajoir, Shibchar, Gopalganj Sadar, Kasiani, Shariatpur S. Bancharampur, Pakundia, Kishorganj Sadar and Gafargaon Sadar (covering 9 upazila in 6 districts	100 options: Dug well, SST, RWHS in each upazila. Total :900 in 09 upazila DW(community type)=50% of the total no. 450. RWHS (House hold type) = 30% of the total no. = 270 SST (Household type) =180	66420

3.5.1 Provision of Alternative Water Supplies

The future plans of several programmes are still unclear and many have not yet finalised the number and locations of arsenic mitigation options to be installed. Furthermore, other programmes (for instance potential support to BRAC from the Royal Netherlands Embassy) are still being designed. However, a review of the available information to date shows that the major programmes with donor support will be undertaking arsenic mitigation in Upazilas where there are a further 5,176 villages with over 80% of tubewells contaminated. These are broken down by individual programme below

Danida: 794 villages (excluding those in same Upazilas as BAMWSP are covering)

BAMWSP: 353 villages

AAN: 15 villages

ADB: 30 villages

UNICEF: 3,984 villages

Total: 5,235 villages

It is not clear whether all these villages will receive all the water supplies required, for instance DPHE-DANIDA have a demand-responsive programme and therefore water supplies will only be provided where these are demanded. This data shows that the existing coverage plus planned coverage has the potential to cover virtually all the emergency phase villages, with a total of 327 villages not covered.

There are villages with lower rates of contamination in the areas covered and it would be expected that the DPHE-DANIDA programme will cover most of these in a demand responsive way. The number of villages with lower rates of contamination covered by DPHE-UNICEF would be expected to be lower than those villages with over 80% tubewells contaminated.

A total number of 46,480 alternative safe water options, 102 community based arsenic removal technologies and 18,774 house hold level arsenic removal filter were installed/distributed in different arsenic contaminated of areas of Bangladesh. Not all the options are installed in the emergency areas. Some are also installed in less contaminated areas. Fig. 3.3 represents the distribution of different arsenic mitigation options in different areas with different level of contamination. The distribution of alternative safe water options according to their category is presented in Figure 3.4. The figure showed that the highest percentage of deep tube wells has been installed as comparing to other alternative safe water options.

3.6 Lessons Learnt

Many lessons have been learnt from the mitigation programmes and projects implemented to date, which have direct bearing upon mitigation policies and programs. Organization specific lessons are mentioned in the organization profile and are presented in Appendix C. A number of lessons having major policy and program implications are as follows:

- Risk substitution is a major problem for many of the arsenic mitigation options and microbial contamination may be significant. In some cases this results in a higher disease burden than the arsenic contaminated shallow tubewells. It is essential that overall water safety is considered and not just arsenic in mitigation programmes.

- Local women with limited educational background can also be trained on awareness development on arsenic, different alternative water supply options, monitoring of the option use in the areas and preliminary identification of arsenicosis patients. Local masons can be trained on the construction and manufacture of different options so that their expertise can be used to the maximum extent. With some training it is possible for female village volunteers to test the tubewells for arsenic. The technology for testing, however, needs further improvement.

- Community mobilization and involvement are essential for arsenic mitigation. People are willing to participate in testing, priority-setting, awareness-building, mitigation and cost-sharing.

- The feasibility, effectiveness, and acceptance of the safe water options available vary from place to place. Some options have been found to be either technically inefficient or disliked by the community; others were found to have good potentials. No single option can be deloyed successfully everywhere, but a combination of solutions must be used.

- Newer options such as piped water supply should be tried for feasibility and cultural acceptance.

- The safe water options installed in the community should be regularly monitored. Water treated by technologies using either surface or ground water should be monitored for different parameters should be monitored for microbiological quality and arsenic.

- There is a need to improve analytical quality control and quality assurance in the use of field kits and in laboratories.

- Assessment of cyanobacteria may be useful for surface water sources depending on whether these are affected by algal blooms.

- Awareness level varies from village to village, and hence the rate of people's switching from contaminated tubewells to 'safe' water sources varies. Villages with arsenicosis patients have the highest consciousness. Effective awareness campaign is necessary to motivate people to drink arsenic free water. Anecdotal evidences suggest not all options provided by the project area equally used.

- Action must be taken to reduce the threat to health from arsenic. The first priority to the arsenic exposed people is to provide them with arsenic free safe water for both drinking and cooking purposes.

- Many treatment units, either home-based or community-based, produce sludge that contains high concentration of arsenic. A countrywide proper management system should be set up so that rural people can manage this sludge in a convenient way.

- There should be more co-ordination among different governmental and non-governmental agencies working in the country.
- It is clear that the technologies introduced to supply arsenic free safe drinking water are only short-term emergency solutions for areas severely affected by arsenic contamination. The longer-term solutions must be based on a long-term vision. This may include the provision of piped water supply to the population and the optimum use of its surface water. The potential role that the local governments can play in this long-term vision must be fully explored.
- It was observed that a lot of motivational work needed to be carried out in the community based for a long term planning of social mobilization to involve the community in owning the projects and sustain the momentum gained in course of implementation of the projects.
- Communities are practicing and habituated with combined water supply systems, i.e. rainwater harvesting in the rainy season and other options in the dry season. Skill building of the private sector (mason, potter etc) should be ensured before introducing new technologies. The local private sector produce low cost innovative model of rainwater harevesting.
- Arsenic awareness programmes have been found to be very effective through conducting the participatory sessions such as Upazila/Union sensitization meeting, courtyard meeting, tea stall session, school awareness program and rally, mobile film show etc.
- Proper operation and maintenance of the water options by the users is generally not satisfactory; more emphasis should be given on this aspect.
- Safe drinking water supply program to improve public health cannot be successful without adequate hygienic latrine coverage. Latrine coverage should be increased.
- People in the arsenic contaminated villages feel the need of using surface water as well as alternative safe water technology. This observation is in line with the existing notion that only information dissemination is not sufficient to mitigate the problem, rather it should be followed by some hardware support immediately.

4

NATIONAL POLICY FOR ARSENIC MITIGATION AND ARSENIC POLICY SUPPORT UNIT

4.1 Summary of the National Policy for Arsenic Mitigation Policy Statement

Ninety seven percent of the population of Bangladesh relies on ground water for drinking purpose. Groundwater has been reported to have contamination by arsenic above the Bangladesh National Standard of 50 µg/l. The percentage of contaminated tube wells in villages varies from more than 90% to less than 5%. Geographically, the tubewells in the delta and the flood plains regions, which comprise 72% of the land area, are more or less affected by arsenic contamination. Different ministries and government agencies, academics, NGOs and bilateral/multi-national development partner agencies are pursuing separate programmes without much co-ordination. This is resulting in duplication of activities and conflicting strategies that inhibit synergy and optimal use of scarce resources. It is a grave public policy concern. Considering the gravity of the situation the government has adopted a statement of policies in 2004 to guide, regulate and control all arsenic related activities so that most people are benefited from both public and private arsenic mitigation programs. The policy aims to:

- providing a guideline for mitigating the affect of arsenic on people and environment in a holistic and sustainable way, and
- supplementing the National Water Policy 1998, National Policy for Safe Water Supply and Sanitation 1998 in fulfilling the national goals of poverty alleviation, public health and food security.

The major policies are follows:

- Ensuring access to safe water for drinking and cooking through implementation of alternative water supply options in all arsenic affected areas.
- Diagnosing all arsenicosis cases and bringing them under an effective management system.
- Assessing the impact of arsenic on agricultural environment and developing appropriate measures to address the problem
- Giving preference to surface water over groundwater as source for water supply;
- Endeavouring to promote piped water systems wherever feasible and such schemes must ensure that the poorest members of the community have access to safe water.

- Pursuing an appropriate mix of preventive and social medicine for treating arsenic affected people;
- Building appropriate capacity at all levels which includes local manufacturing of test kits, local and community level capacity for installation, operation and maintenance of mitigation options, testing, treating, monitoring and surveillance

A National Steering Committee has been formed in order to oversee the implementation of these policies.

4.2 The Implementation Plan for Arsenic Mitigation in Bangladesh

The implementation plan emphasized issues related to safe water supply, health, agriculture as well as cross cutting issues. As regard water supply emphasis is given to screening of arsenic contaminated tubewells and extensive work has been done in this respect. The Implemented Plan identifies four alternative water supply technologies (dug well, pond sand filters, rainwater harvesting and deep tubewells) for arsenic mitigation. The Plan notes that the use of arsenic removal technologies should be subject to their verification by the environmental technology verification process before widespread commercial deployment. The Implementation Plan identifies three phases to mitigation:

Emergency phase (villages with over 80% of tubewells with arsenic above 50µg/l)
Medium-term response (villages with 40-80% of tubewells with arsenic above 50µg/l)
Long-term response (villages with less than 40% of tubewells with arsenic above 50µg/l)

The Implementation plan identifies the need for research and development into water supply technologies, field test kits development and the deeper aquifers. It also calls for ongoing capacity-building at local levels to improve delivery of effective arsenic mitigation.

In relation to health, the Implementation plan identifies some key issues:

1. The case definition protocol to identify arsenicosis patients developed by the national expert committee and subsequently adopted at the WHO regional workshop in November
2. The case management protocol developed by the national experts committee was later adopted
3. Training manuals has been developed in accordance with case definition and management protocol and a simplified draft Bangla version for use of the field workers has also been made that will be finalized soon.
4. An action plan for different levels of health workers training has been developed nation wide by the Directorate General of Health Services with time frame and venue.

In order to implement the policies following institutional plans were adopted:

- All the medical college hospital and national level hospitals will have separate units for management of complicated arsenicosis patients (cancer cases, vascular complicacy etc.).

- All the district level hospitals will have arsenic units.
- There shall be an arsenic unit at the Upazila level involving trained Upazila Health and Family Planning Officer, Resident Medical Officer and Medical Officer and Community Health Workers.
- At the Union level there shall be a union health team with trained health workers. Union Parishad Chairman and Members will facilitate the activities of the health workers in patient management and rehabilitation.
- Private practitioners and health care providers should also be part of patient identification and management programme and should provide information to arsenic unit and should be encouraged to utilize the referral system.

To address the issues regarding the impact of arsenic in the agricultural sector the Implementation notes the need for the following activities:

- Conduct research on arsenic in food chain;
- Conduct research on impact of arsenic on soil quality;
- Investigate into effect of arsenic in agri-chemicals such as fertilizer/ pesticide on agricultural environment;
- Investigate into the effect of arsenic contaminated irrigation water on agricultural product
- Establishment of a national standard for arsenic in ground water used for irrigation and in agricultural products.

4.3 Arsenic Policy Support Unit (APSU)

The Arsenic Policy Support Unit falls under the Local Government Division (LGD) of the Ministry of Local Government, Rural Development & Cooperatives in the Government of Bangladesh. APSU is a small unit that has been established by Government of Bangladesh to support the implementation of the National Policy for Arsenic Mitigation, to support the development of knowledge in key areas of importance to for arsenic mitigation and to support coordination among various organizations working in response to arsenic related problems. The Department for International Development (UK) provides financial and technical assistance to APSU. There is a steering committee for APSU, chaired by the Secretary LGD, who provides overall guidance to the unit. The Project Director and Coordinator of APSU is the Joint Secretary (Water Supply) in LGD. APSU has a full-time International Specialist, a full-time Local Consultant and administrative support staff. APSU regularly contracts short-term local and international consultants to undertake specific time-bound activities related to fulfill its mandate.

4.3.1 Purpose and Objectives of APSU

The purpose of APSU is to provide support to the LGD, other Ministries and Agencies having interest in arsenic and all other stakeholders (NGOs, development partners and academics) in the implementation of the National Policy for Arsenic Mitigation.

The specific objectives of APSU are:

1. To review the policy implications for the adoption of a national programme for arsenic mitigation and to recommend policy refinements, ensure consistency, monitor policy implementation and affect coordination in the sector
2. To support and coordinate activities by relevant GOB Ministries and Agencies, as well as development partners and NGOs.
3. To support monitoring, evaluation and reporting on the arsenic mitigation programme.

4.3.2 APSU Studies and Reports

In order to address key knowledge gaps, APSU has undertaken 16 studies on specific issues relating to arsenic mitigation. Some of these studies are completed and some are on-going and are summarised below. Reports of all these studies can be found on the APSU website (www.apsu-bd.org) or may be obtained from the APSU office.

1. Review of health risk substitution in arsenic mitigation
2. Rapid review of arsenic field-testing kits
3. Analysis of arsenic data from 15 Upazilas in Bangladesh
4. Risk assessment of arsenic mitigation options (RAAMO)
5. Review of the social and socio-economic aspects of arsenic contamination of drinking water
6. Water Safety Plans and applying the WHO Guidelines for Drinking-Water Quality
7. Position paper on arsenic mitigation in Bangladesh (this report)
8. Identification of perennial surface water sources close to villages in the emergency phase
9. Research to optimise surface water treatment using multi-stage filtration
10. Preparation of Union-wise guidance on technology selection for arsenic mitigation
11. Gender issues arsenic contamination
12. Development of a deep aquifer database for DPHE (co-funded with JICA)
13. Preliminary risk assessment of arsenic in food (co-funded by Unicef and FAO)
14. Research into the gender and poverty aspects of access to health care for arsenicosis patients
15. Survey of functional status of arsenic mitigation options installed to date
16. Development of a common evaluation framework for awareness-raising for arsenic

In addition APSU has supported various meetings, conferences and training including support to GOB officials and other staff to attend international workshops and conferences. This has included training in numerical modelling for hydrogeological investigations; support for attendance at a major international conference on water safety in 2003; a national quality conference in 2004; support to attendance by GOB staff at the WEDC conference in Laos 2004;

and a study tour to monsoonal Australia to look at water safety management in small water supplies. Various other smaller-scale training and meetings have also been held.

Health risk substitution in arsenic mitigation

The purpose of this study was to review what maybe the major issues of health concern that should be taken into account when planning and implementing arsenic mitigation programmes and in particular the risk of introducing new hazards as a consequence of mitigating arsenic. The review summarises the key hazards that could substitute for arsenic and sets out in a qualitative ranking the major hazards that will affect the different technologies used for mitigation. The report provides an overview of how the different risks could be controlled and sets out draft water safety plans for the different technologies.

Analysis of arsenic data from 15 Upazilas

The purpose of this study was to undertake a detailed statistical analysis of the arsenic data from the 15 Upazila DPHE-Unicef arsenic mitigation project to investigate what relationships and trends could be detected that would support future decision-making. Data sets for water quality, tubewell age and depth, patients and knowledge, attitude and practice were analysed. Key trends were noted between well age and concentration of arsenic but more limited with depth (CHECK). Numbers of patients were more strongly correlated with concentration of arsenic than proportion of tubewells contaminated which suggests that medical investigations should target those areas with highest concentrations. KAP studies should that awareness programmes had been effective in improving knowledge and attitude, but potentially less so in relation to practice. The performance of test kits is also reported and shown to be acceptable for large-scale screening programmes.

Technical review of field-testing kits

The purpose of the review was to produce an up to date rapid review of the arsenic field test kits available in Bangladesh to provide direction regarding development of a locally produced arsenic test kits and enhancing local provision of kits produced outside Bangladesh. A total of 9 kits were evaluated using data supplied by the producers, experiences from organizations using the kits and some limited independent testing in two laboratories. Four kits were identified as the best performers and there is a need to promote locally available kits using colorimetric method with a digital read out device or colour chart. Interference is noted as problematic and there is a need to improve protection within kits. Quality control in the construction and proper storage of regents was noted as important, as was regular checking of the test kits.

Risk Assessment of Arsenic Mitigation Options

The purpose of this study was to assess and quantify the risk to public health from switching to new sources of water in arsenic mitigation to prevent risk substitution. The study looked at the public health risk potential associated with mitigation options, the social acceptability of different mitigation options and used the information to develop water safety plans for effective water safety management. The study was designed to cover a statistically valid sample of alternative water supplies provided as arsenic mitigation options in Bangladesh. The first phase of the study included assessment of dug wells and deep tube wells in the dry season and the second phase assessed dug wells, deep tube wells, rainwater and pond sand filters in the monsoon and rainwater and pond sand filters in the dry season. The project also developed a tool for estimating the disease burden associated with technologies with an output in Disability-Adjusted Life-Years (DALYs). The results showed that all option have microbial contamination at least some of the time. Dug wells and pond sand filters were the most heavily contaminated and represented a significant risk to public health, which increased in the monsoon. Deep tubewells were of good quality in dry season but had contamination in the monsoon, probably because of the use of contaminated priming water. Rainwater collection quality was better in the monsoon and deteriorated in the dry season, although the public health implications of these are less clear. All options provided water with low arsenic. The findings are now being consolidated into a single report and training courses in risk assessment are planned.

Review of the social and socio-economic aspects of arsenic contamination of drinking-water

The purpose of this review was is produce an overview of the key social and socio-economic aspects of arsenic and arsenic mitigation and to identify how organizations involved in arsenic mitigation have addressed social and socio-economic aspects of arsenic in their programmes. It also identified gaps in knowledge regarding socio-economic aspects of arsenic and suggested how these may be filled, and prepared recommendations for addressing socio-economic aspects of arsenic contamination and its mitigation. Arsenic contamination of groundwater has a number of social consequences. Key social issues include stigmatisation, social exclusion, sustained sharing of water sources, increased water collection burdens for women and girls, possible exclusion of poor households on financial grounds. The review found that although some organisations included some aspects of social and socio-economic issues related to arsenic, this was unconsolidated. Key issues identified included encouraging mitigation programmes to take a social-change approach to mitigation, improving the participation of women and girls in arsenic mitigation, increasing numbers of female staff in mitigation programmes and to improve information-sharing. Key knowledge gaps were identified, particularly in relation to gender aspects, and recommendations made regarding means to fill these knowledge gaps.

Support to implementation of water safety plans

Water safety plans are a key component of the approach to water safety management in the 3rd edition of the WHO Guidelines for Drinking Water Quality, which were published in 2004. Water safety plans are a preventive approach for water safety management from catchment to consumer and place an emphasis on effective operation and maintenance, supported by simple monitoring by water supply operators as the best means of assuring water quality rather than relying on occasional water quality tests. For small water supplies, producing water safety plans is best done by preparing these for technologies rather than individual water supplies. A set of water safety plans for all rural water supply technologies have been developed and piloted through 3 NGOs, DPHE and Unicef. In addition, simple pictorial tools for monitoring of the sanitary condition of the water supply have been prepared for communities to use and are also being tested. To date the experiences have been positive and water safety plans are well-accepted and empowering of communities. Further consolidation of experience will be done in 2005 and the results disseminated in a national water quality conference. Water safety plans will also be implemented in at least two towns.

Identification of perennial surface water sources close to villages with over 80% tube wells arsenic contaminated

The purpose of this study, which is ongoing, is to identify perennial surface water bodies close to the worst affected villages to support planning of mitigation and the use of surface water. A particular emphasis is being placed on the availability of larger water bodies (rivers, canals, baors and haors) rather than ponds. The data is being complied from satellite images and this is being field-checked. The project is currently in a pilot phase to assess its feasibility and is covering 10 Unions with villages with over 80% tubewells contaminated where surface water will have to be used given the absence of a confining layer to allow deep tubewells to be sunk and inappropriateness of dug wells. The implementation phase will progress subject to the findings of the pilot stage and approval by an expert committee of the proposal for the implementation phase.

Development of optimized low-cost surface water treatment

The purpose of this study is to improve the designs currently used for multi-stage filtration units treating water from larger water bodies and connected to piped water systems. To date some so-called river-sand filters have been used to treat water from rivers, canals and baors. The designs used appear to be effective in reducing microbial contamination, but suffer from either being expensive and using materials (such as gravel) that is relatively difficult to source in much of Bangladesh or from using sub-optimal design. A key component of this study is to identify the appropriate grading and shape of brick chips used in the upflow roughing filters, as brick chips will be likely to be primarily used in these supplies. An experimental unit has been set-up and challenge tests of a range of micro-organisms (*E.coli*, culphie-reducing clostridia and coliphage) and chemicals will be performed to assess log reductions. An operational assessment and cost-benefit analysis is also planned.

Support to DPHE to develop Union-wise technology options and guidelines for arsenic mitigation

The purpose of this study is to support DPHE in fulfilling its mandate to develop guidelines for technology options and process of technology selection on a Union-wise basis for arsenic mitigation. A manual will be prepared based on current guidance from DPHE and other stakeholders and on the experience of organisations in arsenic mitigation at a local level. A series of local level consultations will also be held with DPHE and NGO staff to cross-check the recommendations made in the guidance manual. The outputs from the study will be a short report providing a description of the technology and community-based decision-making; a data-book showing recommended technologies by Union; and, a set of maps for easy look-up reference material. Workshops will be held on completion to disseminate the guidance manual.

Development of a deep aquifer database for DPHE (co-funded with JICA)

The purpose of this study is to use existing data held in DPHE, BWDB, WARPO, CEGIS and GSB to prepare a database for tubewells sunk into the Pleistocene aquifer. This database will provide a first step towards the development of a map of the Pleistocene aquifer and will support identifying those areas where deep tubewells can be sunk and areas where the use of deep tubewells should be avoided. The project will take all existing lithological logs and put this into specialist software, which has GIS hooks. Once the data in entered, basic analysis will be performed and a GIS maps produced for regions and if possible for the country. It is expected that the outputs will be available by December 31st 2005.

Research into the gender and poverty aspects of access to health care for arsenicosis patients

The purpose of this study is to investigate whether access to health care for arsenicosis patients is meeting the needs of the population and whether there are any barriers in relation to gender or income level to gaining access to health care. It will also collect information on what type of health care the population would like to have for arsenic. The study will provide recommendations to the health sector on how health care can be improved. Both Government and non-Government services will be assessed to provide a balanced overview of health care delivery. The study will be undertaken in selected Upazilas and will employ triangulated approaches with qualitative and quantitative methods. It is expected that the outputs will be available by December 31st 2005.

Survey of functional status of arsenic mitigation options installed to date

The purpose of this study is to asses how many of the mitigation options installed by different organisations to date are still functioning, whether they have any operational problems and community perceptions of the adequacy of the options. To date over 100,000 options have been installed, but it is not clear how many remain functional beyond the short-term and whether repairs are made when breakdowns occur. It is also important to gain further data on whether particular technologies face operational problems and how well-equipped communities are to resolving these. In order to support ongoing mitigation, community perceptions of the technology and its adequacy are important if particular technologies are to be promoted. The survey will be done in selected Upazilas and will provide information on areas covered by different organisations. It is expected that the outputs will be available by December 31st 2005.

Development of a common evaluation framework for awareness-raising for arsenic

The purpose of this study is to develop an evaluation framework for awareness-raising that all stakeholders can use to develop comparable data. At present, different organisations use different approaches to awareness-raising and as a result it is often difficult to compare the outcomes of different evaluations. At a Working Group meeting on arsenic awareness-raising held at Rajendrapur in December 2003, the participants identified the development of a common evaluation framework for awareness-raising as a key recommendation. This will provide the sector with a much needed methodology and will assist in identifying which approaches and messages are most successful in raising awareness. It is expected that the outputs will be available by December 31st 2005.

5

FUTURE NEEDS FOR EFFECTIVE ARSENIC MITIGATION

5.1 Coordination

Ongoing and improved coordination among the government and the non-government organizations and between different sectors remains the most important issue regarding performing activities on arsenic problem. Very often different organisations have little idea of what other organisations are doing and also weak in disseminating information about their own activities. APSU and BAMWSP have both provided some coordination, but as both projects have limited project timeframes, a mechanism for the future must be developed. This should include both mitigation activities and research work.

5.2 Total Water Quality

The issue of water quality has become a priority after the detection of arsenic in groundwater. However, there are many other water quality issues in addition to arsenic and microbial quality remains a major problems for all rural water supplies. Ongoing work is required to roll-out water safety plans in small community water supplies and to implement an effective ongoing water quality surveillance programme. In addition, establishing specified technologies as health-based targets using risk assessment is essential. This may require a revision of the current Bangladesh standards for drinking-water quality.

5.3 Mapping and Improved Understanding of Groundwater and Mobilization of Arsenic

The research for better understanding of aquifer system as well as the mobilization pattern of arsenic in ground water is a prerequisite of using water from the Pleistocene aquifer. This will help to support effective mitigation of the arsenic problem. A national groundwater mapping and management strategy is required because the aquifer system of Bangladesh is very complex. Fragmental research work or concentrated research work in a single location will not give required out put for taking decision about the whole country.

5.4 Time Series Analysis of Contamination to Identify Future Trends

Time series data generation regarding the contamination of arsenic in ground water is necessary to take decision, whether use of wells should be stopped or can be used on different purposes further. Not only for water but also the agricultural products. Because this will indicate weather the contaminated wells for irrigation can be used further. Withdrawing contaminated ground water will increase the surface load of arsenic.

5.5 Improved Monitoring and Evaluation

After completion of a project, monitoring is necessary to assess whether the mitigation options continues to function and whether it is social acceptable to assess overall sustainability. It has been observed during the information collection that after there is limited ongoing monitoring and evaluation after completion of projects and this needs to be improved.

5.6 Patient Identification and Surveillance

Patient identification programmes should be continued with medical staff and preferably doctors at working at Upazila level to see whether the number of patients is increasing over time and to assess the impact of drinking arsenic contaminated water. This type of monitoring measures should also assess the risk in comparison with number of mitigation option or alternative safe water option provided.

5.7 Commercialisation for Rapid Dissemination

Commercialisation of safe alternative water supply options are necessary for rapid expansion of their use. Private sector should be involved and supported in developing and marketing of appropriate water supply options.

5.8 Local Level Water Quality Testing Capacity Development

The development of capacity at a local level for water quality testing and advice on water safety management is needed to provide support to households and communities in ensuring ongoing access to safe drinking water. Support is already being provided to DPHE for a national laboratory, strengthening the zonal laboratories and equipping DPHE Upazila offices with water quality testing equipment and expertise. However, these still remain remote from many communities and support to LGIs and local private sector to offer services at the Union level would do much to promote improved water safety management.

5.9 Human Resources Development

There is a lack of skilled personnel for installation of the alternative safe water supply options such as dug well, pond sand filter, rainwater harvesting and the hand deep tube well. Such type of personnel development is necessary for sustainability of the mitigation options by organizing training at grass root level of arsenic contaminated area of Bangladesh. Appropriate personnel should be developed to assume specialist functions at different levels of decision-making.

6

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