A STUDY ON ALTERNATIVE SOURCES OF SAFE DRINKING WATER FOR THE ARSENIC AFFECTED AREAS IN KACHUA THANA OF CHANDPUR DISTRICT.

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Certificate of Approval

We hereby recommend that the thesis presented by **M.A. Matin Miah** entitled. **'A Study on Alternative Sources of Safe Drinking Water for the Arsenic-Affected Areas in Kachua Thana, of Chandpur District'** be accepted as fulfilling this part of the requirements for the degree of Master of Urban and Regional Planning (MURP).

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I hereby declare that this thesis has been prepared in partial fulfillment of the requirements for the Degree of Master of Urban and Regional Planning at Bangladesh University of Engineering and Technology, Dhaka and has not been submitted anywhere else for any other degree.

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ABSTRACT

Arsenic contamination in groundwater and its toxic effect on human health is a new public health problem in Bangladesh. In Bangladesh more than 90% of the people are dependent on water supply from the groundwater sources. For more than 50 years, tubewells have been introduced for safe drinking water and domestic purposes. But very recently the arsenic contamination in groundwater and its effect on human health are creating a problem among the people. The study was undertaken to understand the present situation of arsenic contamination in drinking water of Bangladesh. It attempts to know the extent and depth of arsenic occurrence in drinking water of tubewells. DPHE, Grameen Bank, NIPSOM, BRAC, BUET and other NGOs have tested tubewell water in the rural areas of Bangladesh. For this purpose, they have followed both laboratory and field kit methods (specially NIPSOM kit & MERCK kit). Although arsenic contamination was first detected in Bangladesh by the Department of Public Health Engineering (DPHE) in 1993, no remarkable remedial activities were set forth till 1996. According to the latest survey information of the governmental and non-governmental organizations, about 59 Zilas out of 64 are marked as arsenic contaminated areas in Bangladesh About 65 million people live in these Zilas whose total area is 87,390 sq. km. Most of them are living at risk of being affected by arsenic contamination. Arsenic contamination was also found in other parts of the world where no such risk situation is found prevailing as in Bangladesh. A detailed questionnaire survey was conducted to collect information on different aspects of arsenic contamination in drinking water of tubewells in the study area, Kachua Thana of Chandpur District. Using primary and secondary data from reputed and recognized organizations involved in various arsenic oriented programs along with the help of maps and other statistical techniques, the study is formulated. From the study, it is revealed that the on going investigation and measurement techniques of arsenic are not sufficient enough to identity the actual picture of the problem in the country as a whole. To save the people of the arsenic affected areas of Bangladesh, GO's and NGO's are trying to promote different types of water options Kachua Thana of Chandpur District is considered as a vulnerable area of arsenic contamination in its groundwater and different organizations take initiatives to provide safe water options in the territory. The study was under taken to know the extent of the problem and remedial initiatives taken by different organizations in Kachua Thana of Chandpur District.

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AAN	Asian Arsenic Network
ADP	Annual Development Plan
BAEC	Bangladesh Atomic Energy Commission
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council for Scientific & Industrial Research
BGS	British Geological Survey
BRAC	Bangladesh Rural Advancement Committee
BTU	Bucket Treatment Unit
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CB	Coastal Belt
CBO	Community Based Organizations
DANIDA	Denish International Development Agency
DCH	Dhaka Community Hospital
DFID	Department for International Development
DPHE	Department of Public Health Engineering
DSMA	Di-sodium Methanoarsonate
DTW	Deep Tubewell
EGIS	Environmental and Geographical Information System
GB	Grameen Bank
GO	Government Organization
GSB	Geological Survey of Bangladesh
HTW	Hand Tubewell
ICDDR,B	International Centre for Diarrhoeal Disease Research, Bangladesh
IG	Infiltration Galleys
IPGM & R	Institute of Post-Graduate on Medicine and Research
JICA	Japanese International Co-operation Agency
KIDP	Kachua Integrated Development Project
MML	Mott Macdonald Ltd.
MoH&FP	Ministry of Health and Family Planning
MoLGRDC	Ministry of Local Govt., Rural Development and Co-operatives
MSMA	Monosodium Methanoarsonate
MS	Micro-soft
NEERI	National Environmental Engineering Research Institute, Nagpur, India
NGO	Non- Governmental Organization
NIPSOM	National Institute of Preventive, Social and Occupational Medicine
p.a.	per annum
PGM&R	Institute of Post Graduate Medicine & Research
PSF	Pond Sand Filter
PPB	Parts per Billion
PPM	Parts per Million
RAP	Rapid Action Program
RWSSG	Regional Water Supply & Sanitation Group
RVM	Rainwater Harvesting
SDC	Swiss Agency for Development Co-operation
SoES	School of Environmental Studies, Jadavpur University, India
SRW	Sanitary Ring well
SST	Shallow Shrouded Tubewell

STM	School of Tropical Medicine
STW	Shallow Tubewell
TAPP	Technical Assistance Project Proposal
UK	United Kingdom
UNDP	United Nation's Development Program
UNICEF	United Nations International Children for Emergency Fund
VSST	Very Shallow Shrouded Tubewell
WHO	World Health Organization

CHAPTER : 01

Introduction

CHAPTER: 01 INTRODUCTION

1.1 Background and Present State of the Problem :

The arsenic contamination in the drinking water has emerged as a new problem in Bangladesh. During the past three decades, Bangladesh successfully campaigned for safe drinking water from its groundwater resources and as a result, over 95% of its population now depends on groundwater. People have chosen the tube-wells as the easy and convenient method for getting safe drinking water. Some governmental and non-governmental organizations have installed 4 million hand-driven tubewells throughout the country. About 2 million hand-driven tube-wells were installed from 1960 to 1996 with the financial assistance of UNICEF. People have been using this water for different purposes like bathing, washing clothes and principally for drinking and cooking food Unfortunately, it is found that water drawn from underground by tubewells of this territory is severely contaminated with soluble arsenic (Ahmed, 1998).

The Department of Public Health Engineering (DPHE) has conducted many surveys to estimate arsenic contamination in tubewell water samples both at national and local levels Taking into the issue, it has completed a wide survey and has tested water of over 23,000 tube wells. Bangladesh Rural Advancement Committee (BRAC) conducted an extensive semi-quantitative analysis in Hajigonj Thana of Chandpur District that consisted of samples from 12000 wells Dhaka Community Hospital (DCH), in collaboration with the School of Environmental Studies (SoES), Jadavpur University, India, analyzed 8,000 samples and reported that 55 to 60 per cent of the samples from the affected areas contained arsenic having a higher concentration than the acceptable national standard of 0.05mg/L Bangladesh University of Engineering and Technology (BUET) analyzed another 1,210 samples and reported that 61% and 33% of the samples contained arsenic above WHO and Bangladesh Standards for drinking purposes, respectively. Thus several government organizations have launched their programs to detect arsenic polluted areas throughout the country. In 1998, arsenic was found in tube-well waters of different villages under 147 Thanas of 44 districts out of total 64 districts of the country But in 1999, arsenic has been found at 211 Thanas of 59 districts (BBS, 1998). The volume of arsenic affected area has increased by a large amount in the year 1998 than in the year 1997. According to the findings, arsenic contamination in drinking water is high in the southern and north-eastern part of Bangladesh (Khan, 1998).

According to the BBS report 1998, 20 million people of the country have been affected by arsenic and about 70 million people, which is more than half of the total population of the country, are within the risk of being affected by arsenic contamination. It also shows that 10 persons have died from arsenic contamination. The number of arsenic affected people has increased by about 10 million in the year 1998 than in the year 1997 (DPHE, 1998).

Although the arsenic problem of Bangladesh is a problem full of anxiety for public health, no acceptable solution for this problem has yet been found. Moreover, no large-scale project has yet been taken in our country by the government or non-government agencies to prevent an arsenic disaster. Most of the organizations have confined their programs mainly to collect information and research on health condition and education of the people. To overcome the problem or to minimize the effects of this problem, the alternative source of safe drinking water should be identified in context of economic and social affordability of the rural people of Bangladesh.

1.2 Objectives of the Study :

Objectives

The following objectives have been set for the study

- To study the extent and nature of the arsenic contamination in the drinking water in the study area (Data is available from the secondary sources)
- To identify and evaluate the initiatives taken by the governmental and non-governmental organizations to mitigate arsenic contamination in drinking water.
- To find out alternative sources of safe drinking water for the arsenic affected people of the study area.
- To assess community awareness and perception.
- To suggest some policy guidelines to integrate alternative sources to existing sources to mitigate the severity of arsenic problem of rural people in Bangladesh.

1.3 Statement of the Problem :

The specific aims of the study are to find out alternative viable sources of safe drinking water and to formulate some policies for the development of arsenic contamination situation in the study area. This study may also help different governmental organizations and non-governmental organizations to make sustainable projects to mitigate the arsenic contamination problem in drinking water in Bangladesh.

1.4 Rationale of the Study :

This study is highly needed immediately because of the alarming situation of arsenic contamination in drinking water of tubewells in rural areas of Bangladesh. It is expected that the result of the study will provide economically viable source of safe drinking water for rural people. It will also provide some guidelines that may help governmental and non-governmental organizations such as DPHE, UNICEF and DCH to mitigate the arsenic problem in drinking water in rural areas of Bangladesh.

1.5 Selection of Study Area

According to the UNICEF report, 95% tubewell water of Kachua Thana of Chandpur District is arsenic contaminated. Through literature review and reconnaissance survey, it is known that Kachua Thana is one of the most arsenic prone areas in Bangladesh. This pre-concept helped to select Kachua Thana of Chandpur District as the study area. The detail questionnaire survey was conducted in random sampling system to cover the whole area. A base map of the study area was used to show the spatial pattern of arsenic contaminated tubewells and organizational activities in the affected areas in the study area.

1.6 Scope and Limitations of the Study

Due to time and resource constraints, appropriate sample size can not be taken for the study and also the scope is limited to particnlar fields for questionnaire survey.

1.7 Organization of the Study

The thesis is divided into eight chapters to fulfill the objectives of the study.

Chapter 01 basically discusses the background of the problem, objectives of the problem, statement of the problem, rationale of the study, selection of the study area, scope and limitation of the study and finally organization of the study.

Chapter 02 deals with research design and survey methodology. A flow chart is provided to show the design of the process, which includes literature survey, inventory/reconnaissance survey, type of survey, sample size, data gathering method, type of survey data, location, time & day of survey, questionnaire preparation, conducting survey and finally data analysis and representation

Chapter 03 is the literature review section, which talks about different aspects of arsenic contamination in drinking water of tubewell. It includes the topics like, definition, nature, hydro-chemistry & uses of arsenic, arsenic : abundance in nature, presence of arsenic in environment, contamination of the environment with arsenic, cycle of arsenic, toxicity of arsenic, guideline values of arsenic, transformation of arsenic, arsenic removal technologies, arsenic contamination of groundwater and surface water : a global perspective, problems due to arsenic contaminations etc

Chapter 04 includes causes of arsenic contamination, geological origins of arsenic in Bangladesh, brief history of tube wells in Bangladesh, extent of the problem, arsenic occurrence in Bangladesh, arsenic situation according to the national hydro-chemical survey, field test kits, efforts in mitigation of arsenic disaster, role of organizations to combat arsenic problem, alternative sources of safe drinking water in the arsenic affected area, strategic mitigation plan etc.

Chapter 05 comprises some maps showing the location of study area, Kachua Thana including its Unions, distribution of tubewells, ponds and other water options

Chapter 06 contains information (in tabular form) about behavioral, psychological and socio-economic data like age structure, sex, dependency ratio of the family members of the households, educational status, occupation of the family members of the households, monthly income. expenditure of the household per month, information about purpose of use of water from different sources in the study area, about getting sufficient supply of water from tubewells, about availing of water from different sources due to insufficient condition of water supply from the existing tubewells, about the number of family dependent on single tubewell, about the condition of getting sufficient water from the sources throughout the year, about the alternative sources of water in case of getting insufficient water in all the seasons from the existing sources, about availing tubewell water for drinking or any other purposes, about the present condition of tubewell water, about the condition of the arsenic affected tubewells, about the time of detection of arsenic in the tubewell water first, about how the people came to know the presence of arsenic in tubewell water first, about arsenic affected condition in the family member of the households, about the condition of sufferings of the arsenic affected people, about the treatment condition of the arsenic affected people, about the sources of treatment facilities availing by the arsenic affected patients, about working condition of the arsenic affected patients, about the death of the family member of the household due to arsenic affect, about the testing authority of tubewell water, about the marking and using condition of the arsenic affected tubewells, about the purpose of use of water availing from arsenic affected tubewells, about the advising authority not to drink contaminated water, about the condition of availing arsenic free water, about the condition of water filtering instruments, about the condition of availing health service facilities and the providers of facilities, about the existing alternative sources of safe drinking water in the study area, about the drinking condition of water of the existing sources, about the relative distance of the existing sources of drinking water from the houses of the households, about the condition of availing safe drinking water, about the providing authority of safe drinking water, about the quantity of drinking water needed per family per day, about the availability of water from the existing water sources, about the condition of rainwater harvesting technique in the study area, about the time of harvesting rain water by the households themselves, about the purpose of use of harvested rainwater (in priority basis), about the duration of use of harvested rainwater as drinking water, about the assisting authority to exist the rainwater harvesting technique, about the roof material of the household's houses, about the problems related to safe drinking water etc.

Chapter 07 contains findings and recommendations of the study. It comprises the general findings come out from the Analysis Chapter and some policy guidelines to mitigate the problem of arsenic contamination in drinking water in tubewells in rural areas of Bangladesh

CHAPTER : 02

Research Design & Survey Methodology

CHAPTER: 02 RESEARCH DESIGN & SURVEY METHODOLOGY

2.1 Introduction :

Outline of methodology/experimental design is limited to literature survey, inventory/reconnaissance survey, selection of sample size, questionnaire preparation & survey, discussion with concerned authorities & local bodies, data analysis & representation. The following methodological procedures are followed to fulfill the objectives of the study and it is shown in a flow diagram.

2.2 Literature Survey :

An intensive literature survey was undertaken to acquire knowledge regarding arsenic contamination in water in tubewells in different areas of Bangladesh. Attempts were taken to gather information regarding arsenic contamination of groundwater both in Bangladesh and abroad.

2.3 Inventory/Reconnaissance Survey :

Initial inventories/reconnaissance survey has been done to identify the proper location of the study area, to locate the distribution of the tubewells, ponds, river and other sources of safe drinking water in the study area.

2.4 Survey Design :

Survey design of the study is divided into five steps. They are types of survey, sample size, data gathering method, selection of location, time & day of survey

A simple random survey and visual survey has been selected to achieve the objectives of the study.

A sample size of 200 households (about 39% of the total population of the study area) has been pre selected from 50262 households in 12 Unions named Ashrafpur, Bitara, Uttar Gohata, Dakshin Gohata, Uttar Kachua, Dakshin Kachua, Kadla, Karaia, Purba Pathair, Paschim Pathair, Purba Sahadevpur and Paschim Sahadevpur.

Face to face interview has been conducted to gather data using a detailed questionnaire. Direct visual observation has done to identify contaminated tubewells, sources of water, collection of water by the villagers, location of the alternative safe water options and the affected people in the study area.

The survey data comprises a combination of profile data, psychological and behavioral data.

Time selected to questionnaire survey is off class hours and days are weekdays. The location is Kachua Thana of Chandpur district. It is 80 miles away from Dhaka.

2.5 Questionnaire Preparation and Survey:

A detailed questionnaire was prepared and a survey was conducted to study the arsenic contamination problem in tubewell water, its consequences and to find out the viable safe drinking water options in the study area. Emphasize was also given to study different aspects of the problem, present condition of water sources, people's attitude to use tubewell water, severity of the problem, awareness of the people about the problem, alternative water options, proximity of the options, cost to set up the alternative safe water options, their economic viability coping with the problem and some open ended questions to know household's perception in finding solution of different problems related to arsenic contamination in tubewell water in Kachua Thana of Chandpur District.

2.6 Data Analysis& Representation :

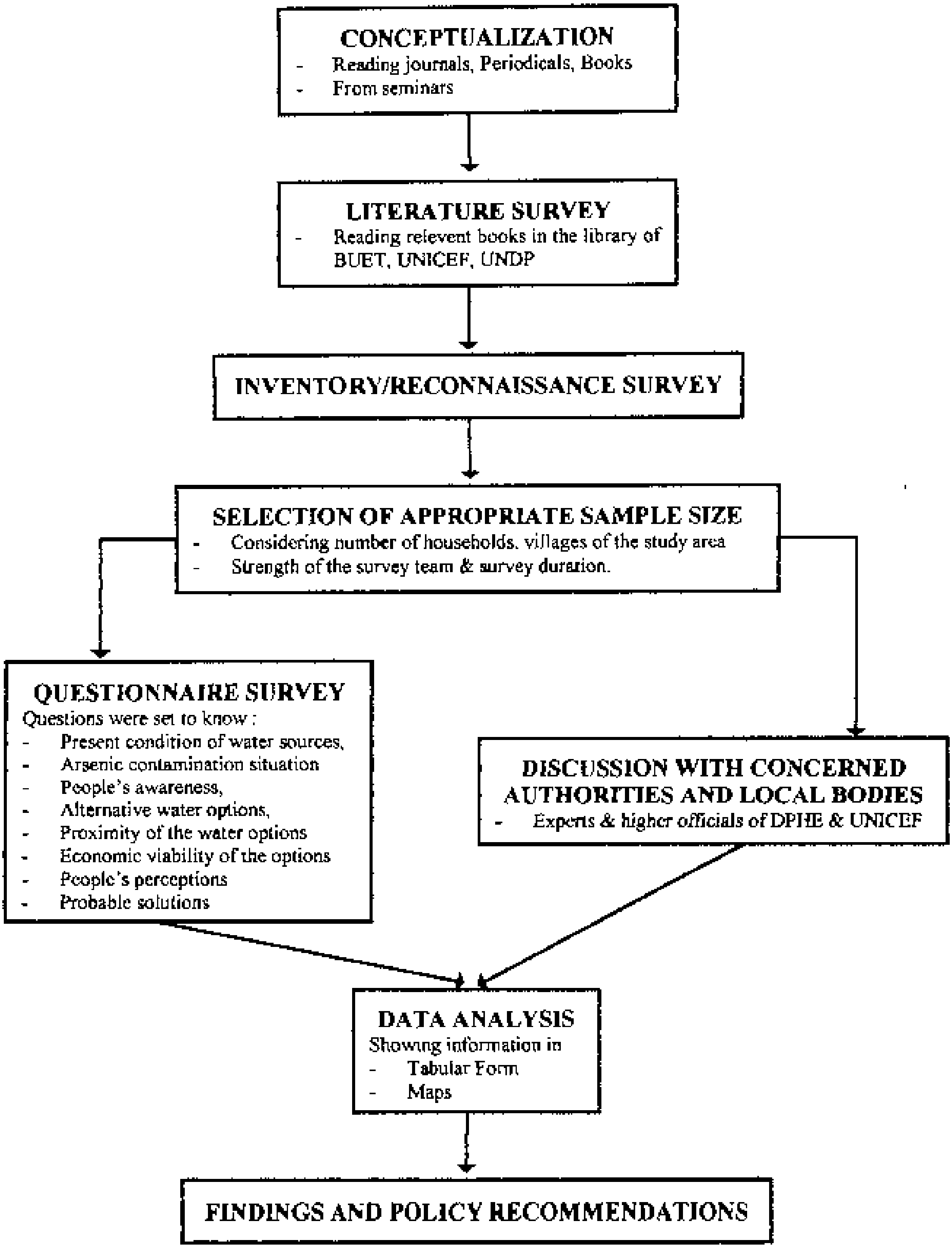
MS Word, and Excel were used as the main tool in analysis of the data. Simple frequencies, percentage and cross tabulation were done for the study.

2.7 Map Preparation :

Several area maps are prepared to show the distribution of arsenic contaminated tubewells, arsenic affected areas,and distribution of alternative water sources in the study area.

Flow Diagram-01:

FLOW DIAGRAM OF RESEARCH DESIGN



CHAPTER: 03

Literature Review

3.1 Introduction :

In this Chapter relevant literature has been reviewed to get a better understanding of different issues related to 'Alternative Sources of Safe Drinking Water for the Arsenic Affected Areas in Kachua Thana of Chandpur District'.

What is Arsenic :

Arsenic (As) is a semi-metal. It is derived from the Greek name "arsenikon" originally applied to mineral 'Orpiment' (Alam et al., 2000) Its chemical properties and position in the periodic table reveal it to be a nonmetal with certain properties of metals. It is often called a metalloid Arsenic is a native element. It is gray or white in color (DCH, 1998). It is found in the nature as inorganic and organic compounds. Inorganic arsenic is more toxic than the organic ones. Inorganic arsenic is divided into two types: trivalent and pentavalent. The trivalent inorganic arsenic is 60 times more toxic than pentavalent arsenic (Hossain, M. 1996). Trivalent arsenic compounds are known as arsenate and the pentavalent as arsenite. Usually, four types of arsenic compounds exist in water. These are arsenite, arsenate, monomethyl arsenic acid and dimethyl arsenic acid. But in the groundwater, arsenic predominantly occurs in the trivalent and pentavalent forms. These two have been found in the groundwater of Bangladesh and West Bengal (DCH, 1998).

As many as 150 species of arsenic bearing minerals exist in the earth, bid only three of them are considered as arsenic ore. Because, the amount of arsenic is higher in these compounds. Moreover, they are more available than other arsenic compounds. These dim compounds are Realgar or arsenic disulfide (As_2S_2); orpiment or arsenic or arsenic tri-sulfide (As_2S_2) and arsenopyrite or ferus arsenic sulfide (FeAsS). There are differences in the physical properties of these three types of arsenic minerals, bid a common feature of them is garlic like odor. Arsenopyrite has been p6marily identified as the main source of arsenic pollution in the groundwater or Bangladesh and West Bengal (DCH 1998) When arsenopyrite oxidized and mixed with water, no smell is found in the water. The major minerals of arsenic are as follows (Alam,K.1998) : Arsentopleite [$CaFe_4(AsO_4)_4(OH)_4.4H_2O$], Arsenite [$Pb_3MnH(AsO_3)_3$]; Arsenobismite [$Bi_2(AsO_4)(OH)_3$]. Arsenolite [($AS_2O_3$]; Ascnopalladinte [$Pb_8(AsSb)_3$]; Arsenopolubasite [$(AgCu)_{16}(AsSb)_2S_{11}$]; Arsenuranulite [$Ca(Uo_2)(AsO_4)_2(OH)_4.6H_2O$]; Silver arsenite [$Ag_3AsO_3$]; Cupric Arsenite [$Cu_3(AsO_3)2H_2O$]; Goldfieldite [$Cu_2(SBAS)_4(TeS_{13})$]

Arsenic and its Use :

Use of arsenic dates back to early as early as 3000 BC when arsenic compounds were employed in bronze alloys (Partington, 1935) and were used for medicaments well before 400 BC. Use of arsenic compounds for insecticides dates back to ancient times. The Chinese are believed to have used arsenic compounds as insecticides as early as 10th century AD. During the Middle Ages, arsenic compounds were widely used in agriculture (Whorton, 1969). The invention of Paris Green (copper acetoarsenite) as an insecticide to control potato beetle in 1868 by an American farmer began the widespread use of arsenic in agriculture. The success of Paris Green prompted the trial of London Purple (a mixture of calcium arsenates and arsenites with some organic matter) as an insecticide and this was also quickly adopted by the agriculture industry (Whorton, 1969).

Arsenic compounds are being used in various industries. The list of uses of arsenic compounds is shown in **Table-01**

Table-1 : Main Uses of Arsenic Compounds

Arsenic		Uses	
Arsenic metal	:	▪ In alloys (in combination (0. 5% As) ▪ Industrial battery grid	▪ Electro-photography
High purity arsenic	:	▪ Semiconductor applications ▪ Solar cells	▪ Optoelectronic devices ▪ Photoemissive surfaces
Calcium and lead arsenate Arsenic Acid	:	▪ Pesticide on fruit crops ▪ Wood preservative salts	▪ Desiccant or defoliant
Sodium Arsenite	:	▪ Cattle and sheep dips ▪ Debarking trees	▪ Aquatic weed control ▪ Defoliant for potato
Refined arsenic trioxide	:	▪ Decoloriser and as oxidation/reduction buffer in the production of glassware.	
Paris Green (copper acetoarsenite).	:	▪ Sprays on apples and cherries, vegetables and small fruit, baits and mosquito larvae	
Arsenic sulphide	:	▪ Pyrotechnics	▪ Depilatory (leather industry)
Arsenic and arsenic acids	:	▪ Additives to motor fuel ▪ Corrosion inhibitors in steel	▪ Herbicides, fungicides and bactericides ▪ Feed additives

Source: Nriagu & Azeue, 1990

Arsenic Abundance in Nature :

Karl Vogel wrote about arsenic in 1928 "*It is an uncanny thought that this lurking poison (arsenic) is everywhere about us, ready to gain unsuspected entrance to our bodies from the food we eat, the water we drink and the air we breath*"

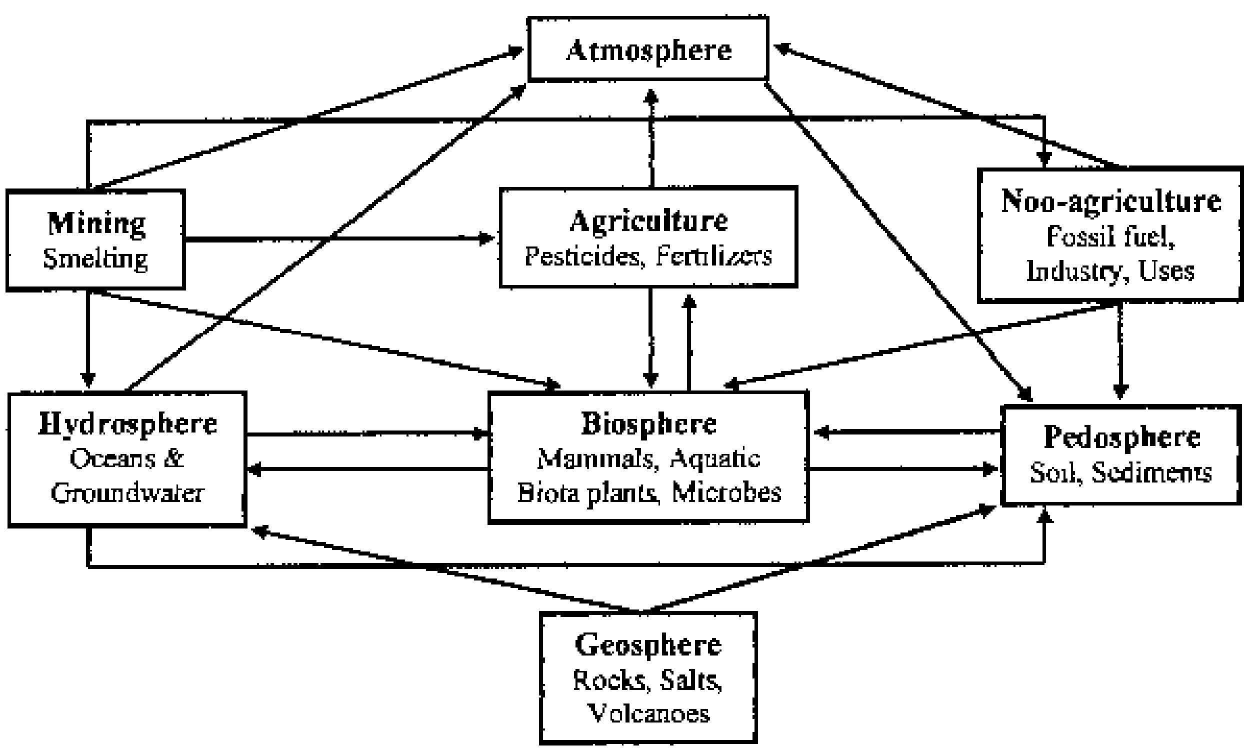
This emphasizes the occurrence of arsenic in all natural environments i.e. in lithosphere, hydrosphere and atmosphere. The natural concentrations in most cases are harmless to public health. Recent increases in anthropogenic activities have resulted in elevated arsenic concentrations in different environments and pollution of air, soil and water has become a serious health hazard in different parts of the world. Arsenic concentrations in igneous, metamorphic and sedimentary rocks vary considerably and these are the main sources of arsenic in aqueous system. Sedimentary rocks generally contain more arsenic than igneous and metamorphic rock. Suspended and bottom sediments in most aquatic systems contain much higher concentrations of arsenic than in water. Coal can contain as much as 2000 mg/kg of arsenic (Onishi, 1969).

Arsenic is a ubiquitous element being widely distributed in the earth. Nature itself is a source of arsenic. According to availability of natural elements in environment, the position of arsenic in 20th. The arsenic contents of the earth's crust is 1.5-2 mg/kg. However, arsenic up to 550 mg can prevail in per kg polluted soil. Arsenic poison can spread in air from the industrial wastes. Generally, nominal amount of arsenic also exists in water, per liter natural water contains 1-2 microgram of arsenic. Traceable quantity of arsenic is also found in most of fruits, vegetable, fish and meat But high level of arsenic exists in seawater. Foods of marine origin are much richer in arsenic than other foods. Arsenic up to 5 microgram can be found in per kg of sea fish. Arsenic also exists in lava of volcano. Geothermal system and uranium and gold mines are the sources of the arsenic. It occurs in the air in areas where coal is bnrnt, particularly near smelters and refineries (DCH, 1998).

Cycle of Arsenic :

The environmental cycle of arsenic is shown in the flow diagram-02.

Flow Diagram-02: The environmental cycle of arsenic (Bunmbla and Keefer, 1999)



Source : Khan, Mohiuddin Md. Timur, (1999), A study on Techniques of Arsenic Removal from Drinking water, An MS thesis, Department of Civil Engineering, BUET.

3.2 Contamination of the Environment with Arsenic :

The application of arsenic herbicides and pesticides represents a primary source of environmental pollution with arsenic. Manufacturing of arsenical pesticides can result in the discharge of arsenic during transportation, distribution and storage to the environment. The cumulative quantity of pesticidal arsenic that has been released to the environment is substantial. It has been suggested that on a global basis, 65% of the airborne arsenic is derived from the smelting of base metal ores (Nriagu and Pacyna, 1988). Burning of timber treated with cacodylic acid has been found to be an important source of airborne arsenic acid in the UK and the disposal of the ashes of such timber contributes significantly to the arsenic burden of the soil (Hutton and Symon, 1986). The main sources of arsenic pollution in surface waters include domestic and industrial wastewater, electrical power plants, base metal mining and smelting, and fall out of contaminated aerosols. Arsenic in soils can be derived either naturally from weathering of arsenic containing rocks and minerals or through inputs of wastes from human activities.

Toxicity of Arsenic :

1. Arsenic and certain arsenic compounds are known carcinogens.
2. Amount of arsenic intake required to cause harmful effect depends on the chemical and physical form of arsenic.
3. Inorganic forms of arsenic are more toxic than organic forms.
4. Water soluble forms are more toxic
5. Humans are most sensitive to arsenic than animals.
6. Studies in humans indicate considerable variation among individuals
   - Some humans can ingest over 150 μg/kg/day without/ apparent ill-effects
   - Sensitive individuals are affected at 20 μg/kg/day (1000-1500 μg/kg/day for adults)
7. Doses of 600-700 μg/kg/day (around 50,000 μg/kg/day for adults; 3,000 μg/kg/day for infants) have caused death in some cases.

3.3 Provisional WHO Guideline Value for Arsenic :

The WHO Guideline value of a substance is established as the concentration in drinking water associated with an estimated excess lifetime cancer risk of 10^{-5} i.e. one additional incidence of cancer per 100,000 population ingesting drinking water with the substance at the guideline valne for 70 years. The WHO also establishes provisional guideline value; the term 'Provisional guideline value' is used when :

- There is some evidence of a potential hazard but where the available information on health effects is limited,
- The calculated Guideline Valne is below the practical quantification level;

- The calculated health-based Guideline Value is below the level that can be achieved through practical treatment methods;
- It is likely that the health-based Guideline Value will be exceeded as a result of disinfection procedures (WHO, 1993).

WHO established the guideline value of 0.01 mg/L or 10μg/L for arsenic in 1993 (WHO, 1993) recognizing the facts that ·

- Inorganic arsenic is a documented human carcinogen.
- The guideline value of arsenic in drinking water based on health criteria is too low for practical implementation/compliance in water supply.
- The guideline value for arsenic is restricted by measurement limitations, and 0.01mg/L is the realistic limit for measurement.
- Most treatment process can reduce arsenic to 0.01 mg/L

National Standards for Arsenic :

The WHO guideline for drinking water quality is suggested for use as a basis for the development of the national standards. The local or national environmental, social, economic and cultural conditions are considered to fix up the standard.

Table-2 : The currently accepted national standards of few countries for arsenic in drinking water

Countries	Standard, mg/L
Australia (1996)	0.007
European Union (1998)	0.01
Japan (1993)	0.01
Jordan(1991)	0.01
Laos(1999)	0.01
Mongolia (1998)	0.01
Namibia	0.01
Syria (1994)	0.01
USA (2001)	0.01
Canada	0.025

Countries	Standard, mg/L
Bahrain	0.05
Bangladesh (1997)	0.05
Bolivia (1997)	0.05
China	0.05
Egypt(1995)	0.05
India	0.05
Indonesia (1990)	0.05
Oman	0.05
Mexico*	0.05
Philippines (1978)	0.05
Saudi Arabia	0.05
Sri Lanka (1983)	0.05
Viet Nam (1989)	0.05
Zimbabwe	0.05

* Considering to lower the standard from 0.05 mg/L

Source . Ahmed, M. F., 2003, Arsenic Contamination : Bangladesh Perspective.

The WHO provisional guideline value of 0.01 mg/L has been adopted as the national standard for arsenic in drinking water in many countries of the world, while many other countries have retained the earlier WHO guideline value of 0.05 mg/L as the national standard or as an interim target Some of the countries are trying to adopt lower standard for arsenic in drinking water Guideline values or standards indicate the maximum allowable limit but it is always desirable to reduce arsenic content in drinking water as low as possible. The financial burden of lowering acceptable levels of arsenic in drinking water is huge for the countries like Bangladesh where most of shallow aquifers mainly used for water supply are contaminated. Table 1 shows the currently accepted national standards of selected countries for arsenic in drinking water (Yamamura, 2002)

Bangladesh Standard for Arsenic :

In Bangladesh, the first water quality standards were published in December 1976 by the then Water Pollution Control Board. These standards relate to water quality parameters for drinking water, recreational water and fishing water. The drinking water standards were based on the WHO 1963 and 1971 International Drinking Water Standards, with some minor modifications (Ahmed,M.F ,2003). In 1984, WHO published guideline values to promote development of national standards depending on the existing quality of water, economic and social conditions and technical capabilities of individual countries. Since then a revision of Bangladesh Water Quality Standards was felt desirable by the authorities concerned. The Government of Bangladesh constituted an expert committee in 1988 to prepare a comprehensive environmental quality standard (EQS) for Bangladesh. In the mean time, Bangladesh Standard Specification for Drinking Water (BDS 1240 : 989) was prepared and published by the Bangladesh Standard and Testing Institution (BSTI) with 0.05mg/L as standard for arsenic in drinking water

Compliance with WHO Guideline Value :

It is evident that arsenic at low concentrations can pose a risk to human health. So it is essential to keep the arsenic content in drinking water as low as possible. But considering the existing modes of water supply, technical and economic conditions, it is not always possible for many countries to comply with the WHO provisional guideline value or a lower standard for arsenic in drinking water. The lower standards in some countries would imply prohibitively large increase in the cost of water treatment or abstraction of alternative safe water sources. Some of the immediate problems to adopt a lower standard for arsenic include:

- Abandoning of many existing water supply systems.
- Abandoning of existing treatment facilities for their inability to reduce arsenic content to desired level.
- Huge cost of development of alternative water supply systems.
- Lack of adequate monitoring capabilities to implement the revised standard.

The adoption of the WHO guideline value as the standard for arsenic is much more difficult in Bangladesh. The possible implications are

- an estimated 46% of the tubewell will have to be declared unsuitable for drinking water supply.
- the low-cost coagulation based water treatment options and existing natural iron based water treatment facilities established in few urban centers are to be abandoned;
- alternative water supply systems are to be developed for 49 million people exposed to arsenic higher than 10μg/L;
- the existing arsenic testing facility by field kit at local level to be discontinued because of its low accuracy at 10 μg/L level and replaced by costly laboratory methods.

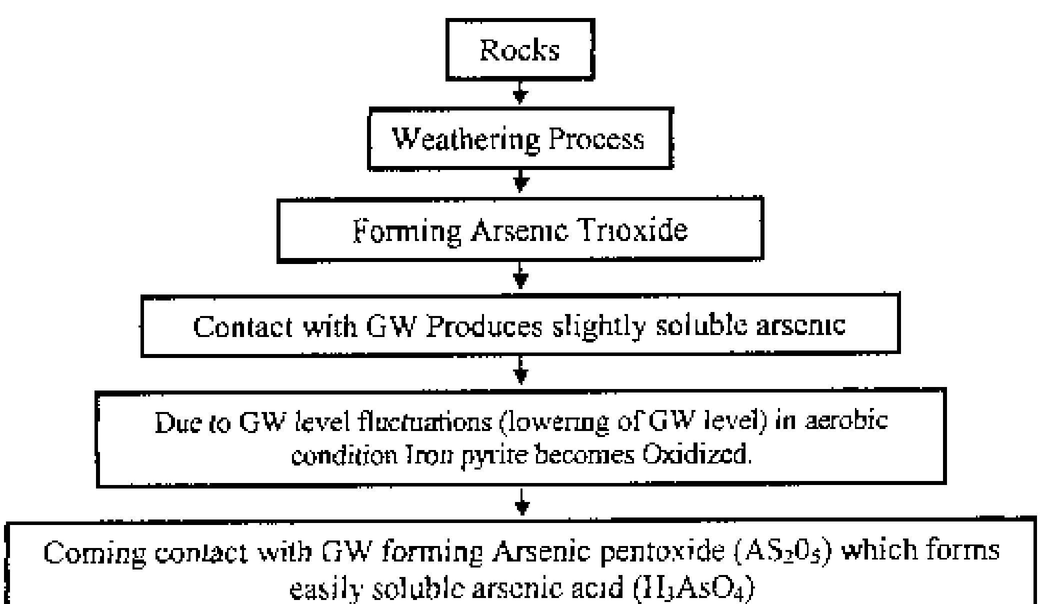
Table-3 : Parameters for establishing Guideline Values for drinking water.

Parameters	WHO Standard Value	Bangladesh Value (Assumed)
Water Consumption	2L/Capita/day	3L/Capita/day
Body weight	60 Kg.	60 Kg.
Life span	70 years	68 years

Source : Ahmed, M. F., 2003, Arsenic Contamination : Bangladesh Perspective.

3.4 Arsenic Transformation Mechanism :

Geologically deposited alluvial sediments containing sulphide minerals i.e , Realgar (Arsenic sulphide AsS), Orpiment (Arsenic Trisulphide As_2S_3) and Arsenopyrite release arsenic to the nature by weathering process. The Ganges river carried sediments containing pyrite, arsenopyrite and pollutes the groundwater with arsenic.



Source : Rahman, M. H., Islam, M. B., Ahmed, Mushfique, 1997.

Arsenic Removal Technologies :

The relative advantages and disadvantages of different methods have been presented in the **Table-4.**

Table-4 : Conventional Arsenic Removal Technologies:

Technologies	Advantages	Disadvantages
Co-precipitation : • Alum Coagulation • Iron Coagulation • Lime Softening	• Relatively low capital cost • Relatively simple operation • Common chemicals available	• Produces toxic sludge • Low removal of As(III) • Pre-oxidation may be required • pH Adjustment is required
Corption Techniques : • Activated Alumina • Iron Coated Sand • Ion Exchange Resin • Other Sorbents	• Relatively well known and commercially available • Well defined technique • Plenty possibilities and scope of development	• Produces toxic solid waste • Replacement/regeneration required • High tech operation and maintenance • Relatively high cost
Membrane Techniques : • Reverse osmosis • Electro-dialysis	• Well defined and high removal efficiency • No toxic solid wastes produced. • Capable of removal of other contaminants • Should be less costly • Higher effectiveness	• Very high capital and running cost • High tech operation and maintenance • Toxic wastewater produced
Microbial Processes : • Microbial Oxidation • Microbial Removal	• Should be less costly • Higher effectiveness	• Not yet fully established • Require extensive research

Source: Ahmed, M.F., 2001, Water Supply Options in Arsenic Affected Rural Areas.

3.5 Arsenic Contamination of Groundwater and Surface Water: A Global Perspective :

Arsenic Contamination of Groundwater :

Arsenic is the twentieth most abundant element in the earth's crust. It has an average crustal abundance of approximately 2 mg/kg Under certain conditions it can occur at considerably higher concentrations in groundwater that causes most health-related problems.Investigations over the last few years have identified problems with arsenic in groundwater in a number of different hydro-geological environments and new arsenic-rich groundwater are being found in many countries.

Arsenic has long been a recognized problem in sulphide mining areas in many parts of the world. Mining operations enhance the degree of oxidation of arsenic-rich sulphide minerals and lead to release of arsenic to groundwater and surface water. Such contamination problems are often severe locally as a result of the potentially very high concentrations present in sulphide minerals. Elevated arsenic concentration due to natural geological sources has been reported from different parts of the world such as Taiwan, Argentina, USA, Mexico, West Bengal, India etc. Similarly cases of elevated arsenic concentrations due to pollution from anthropogenic sources have also been reported from Behala in Calcutta (due to disposal of arsenic from a *Paris Green (acetoarsenite)* manufacturing plant and Ghana (due to gold mining activity). Major arsenic contamination in groundwater has been reported from the following countries:

3.5.1 Argentina :

Several regions of Argentina have been affected by natural arsenic contamination of which the Cordoba province in the central part is the best studied. High arsenic levels in drinking water ranging up to more than 2.0 mg/L have been repeatedly measured. About 55,000 people have been drinking water with more than 0.05 mg/L. Other extensive areas of arsenic contamination of groundwater are found in Argentina. The source of the contamination is natural, related to the rock composition of the area.

The first notification of waterborn arsenicosis was as early as the beginning of the 20^{th} century. The term ***"Bell Ville disease"*** was used to describe skin manifestations causes by arsenic. About 2 million people are exposed within about 1 Km^2 affected area in Argentina.

3.5.2 Australia :

There are thousands of arsenic contaminated sites in Australia (Jack, C.N.,1997).

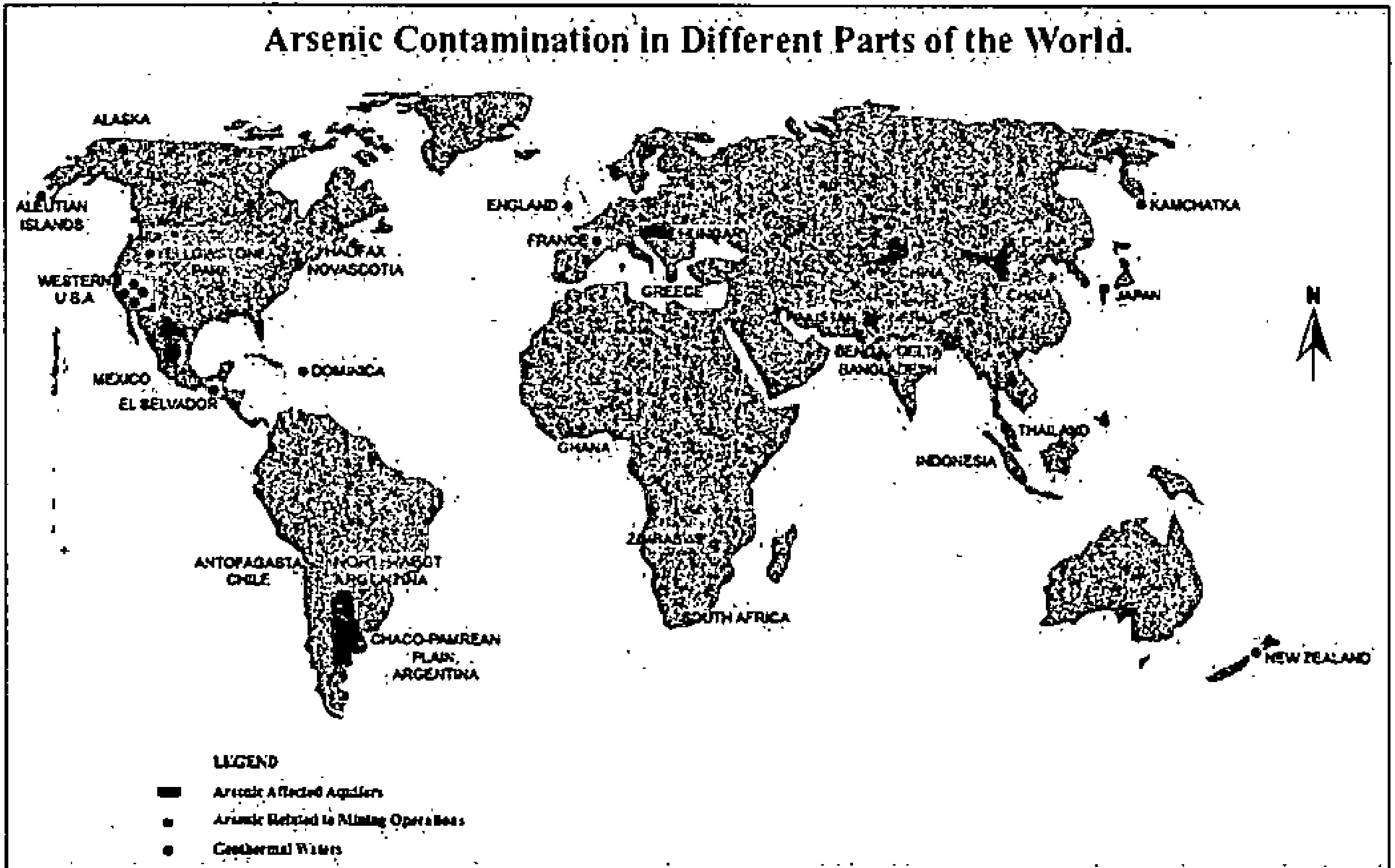
3.5.3 Cambodia :

First detected during 1999/2000, 100 samples indicating 9% above WHO Provisional Guideline Value (GV) of 0.01mg/L. Since then, 1,739 samples have been tested in 15 provinces indicating 5% above Cambodian provisional level of 0.05mg/L and 14% above WHO GV of 0 0 1 mg/L Arsenic in some wells in Kandal province found to be above 1.0mg/L. Suspected arsenicosis patients found the province show urgent need for wide scale testing. Possibly 2 million people are at risk.

3.5.4 Chile:

Chile is an example of surface water contamination by arsenic from natural sources. The north part of the country has a history of arsenic exposure. It extends over an area of 125,000 sq. km. with a population of over 400,000. The area has limited sources of groundwater. The public water supply of the area brings water from the rivers high in the Andes by aqueducts. A number of rivers originating in this area are naturally contaminated. In 1957 and following 12 years drinking water contained 800- 1,300μg/L of arsenic. In 1962 the first cases of arsenicosis were reported. It is estimated that 7% of the deaths from 1989-1993 are caused by previous exposure to arsenic.

Map : 01



Source : Ahmed, M.F., Arsenic Contamination : Bangladesh Perspective, 2003.

3.5.5 China :

The first case of arsenic poisoning was discovered in 1990 Many of the arsenic affected areas are located in the arid region (rainfall 200-300mm p.a.). An estimated 5.63 and.14.66, million people in 29 out of 32 provinces of China drink water containing arsenic exceeding 50μg/L and 10μg/L respectively. The highest concentration detected in the well water was 2460μg/L (Ahmed, M F., 2003). More than 30,000 cases of arsenicosis diagnosed so far. More serious effects were detected in China including high cancer mortality. Chronic arsenic poisoning from using arsenic and fluoride rich coal was reported in Guizhou province

3.5.6 England :

A cohort of 478 patients treated with ***Fowlers Solution*** (Potassium Arsenate) in England during the period of 1945-1969 has been passively followed until the end of 1990 (Evans, S , 1997). A small area study of environment on arsenic contamination and risk of bladder cancer in Devon and Cornwall South-East of England was found affected (Globanni, S , 1997).

3.5.7 Ghana :

The rivers in the Obuasi region of Ghana present another example of contamination of surface water by anthropogenic activities (Smedley et al , 1996). The concentration of arsenic in the Kwabrafo River was 7.9 mg/L The high concentration was attributed to mine pollution and oxidation of arsenopyrite.

3.5.8 Hungary :

Before 1984, the arsenic content of piped water in Karcag the great plain of Hungary with 24,000 inhabitants, was between 0.096 and 0. 130 mg/L (Csanady, M , 1997). Arsenic contamination has been identified in groundwater in alluvial sediment in the southern part of the Great Hungarian Plain and about 1,10,000 sq km in area consisting of quaternary sediment are affected. Total Population exposed to arsenic contamination is about 29,000. Arsenic concentration was fonnd in the ranges of <2 to 176 μg/L.

3.5.9 India

Arsenic contamination in groundwater in some districts of India is detected and they are as follows: Malda, Mursidabad, Nadia, 24 Parganah (Mazumder,*et al.*, 1992). Among them groundwater of Calcutta has been contaminated by man made sources. Groundwater in the Behala area of the city has been contaminated by arsenic from a factory that had been producing '***Paris Green***' for 20 years. The liquid waste from the factory was discharged into an open drain connected to a canal Water samples from shallow tubewells, deep tube wells and tap water from piped water supplies were analyzed. Eight of 12 deep tubewells analyzed had <0.05 mg/L of arsenic and the remaining four in between 0.06-0.42 mg/L. Out of 45 shallow tube wells 17 had contained arsenic in the safe level and 28 had concentrations from 0. 1 to 58 mg/L (10 with more than 5 0 mg/L) All the six tap water samples had arsenic less than 0 05 mg/L (Mandal, B K., 1996).

3.5.10 Mexico:

Armienta (et al, 1995) describe arsenic contamination in groundwater of Zimpan Valley near Mexico City due to mining activities. Zimpan has been a mining district since the seventeenth century, involving exploitation of silver, zinc and lead by selective flotation. Solid wastes have been piled up on the ground without any protection. Leaching of this solid waste has polluted groundwater. Water samples were collected from dug wells and deep tube wells. Twenty-two groundwater samples were found to be contaminated with arsenic at concentrations of more than 0.028 mg/L, 19 had concentrations above the drinking water limit (0.05 mg/L).

3.5.11 Mongolia:

Luo *et al.* (1997) describes the case of Inner Mongolia where arsenic contaminated groundwater occurs in a sunken lake basin covering an area of 4800 km2. The subterranean water occurs in Quaternary deposits and has a naturally occurring high concentration of arsenic from the local rock High levels of arsenic (Mainly AS^{+3}) and bicarbonate are found in the water. The aquifers provide a reducing environment, rich in organic substances, in which arsenic easily moves and accumulates.

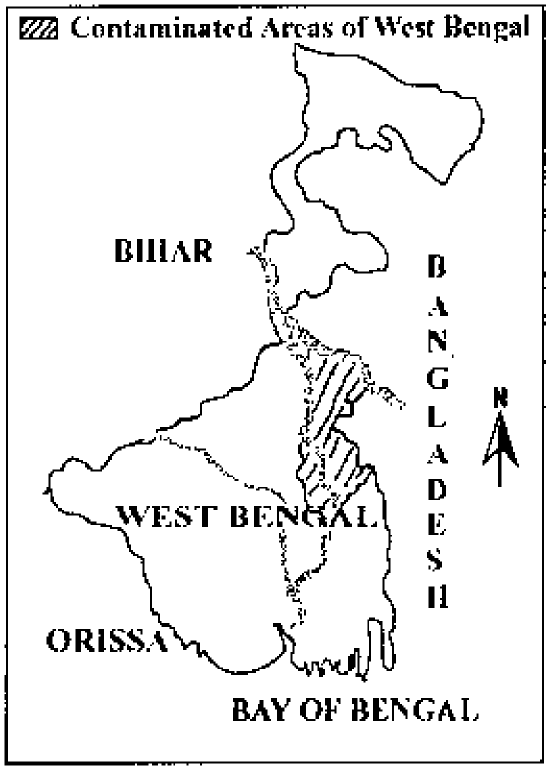
3.5.12 Nepal :

Arsenic contaminated tubewells have been identified in 20 Terai districts. Estimated population exposed to arsenic exceeding 50µg/L is 550,000 (2 4% of population).

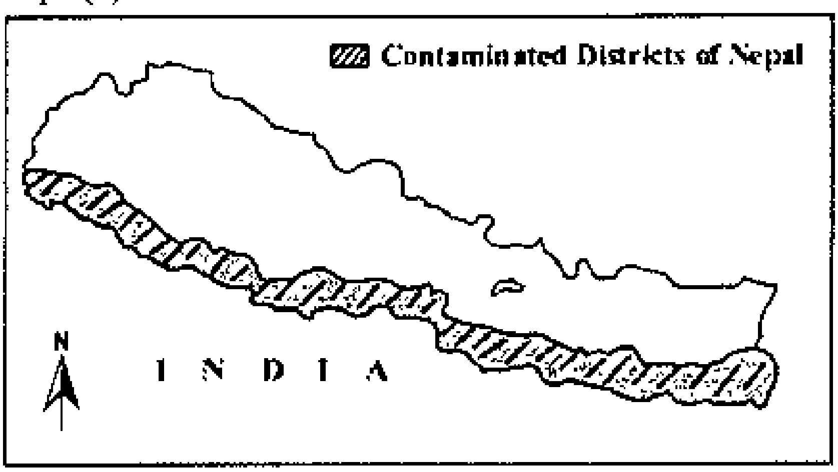
3.5.13 Pakistan :

Some arsenic contaminated water sources have been found in Punjab and Sind Provinces of Indus basin. Preliminary study indicated that about 1% sources were contaminated with arsenic exceeding 50µg/L and 11% sources had arsenic content within 10-50µg/L. The intensity of arsenic contaminated sources is higher in Sind as compared to Punjab.

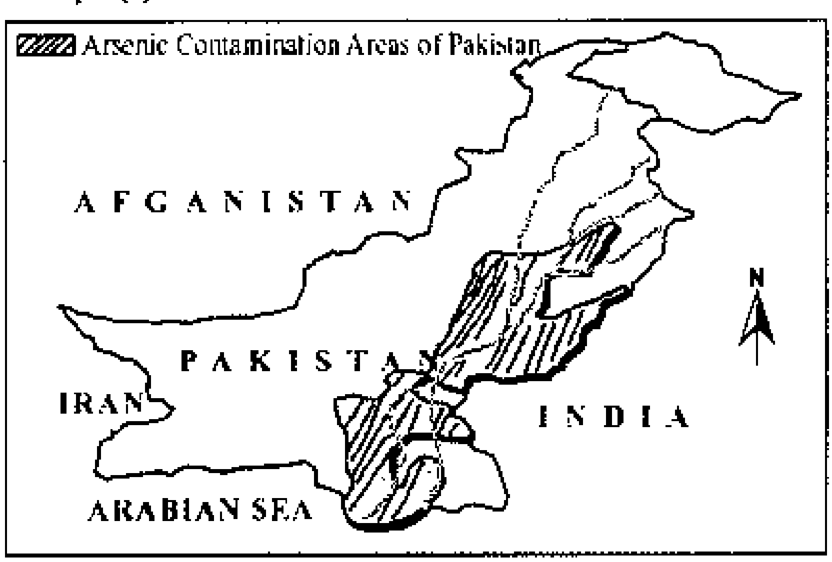
Map-2(a)



Map-2(b)



Map-2(c)



Source : Ahmed, M. F., Arsenic Contamination : Bangladesh Perspective, 2003.

3.5.14 Taiwan :

The arsenic problem in Taiwan was first reported in 1968. Taiwan gave arsenicosis the name ***"Black Foot Disease"*** first. From the survey of over 83,000 wells, it is found that 19% of the wells had arsenic levels over 50µg/L. Moreover potential of cancer risk due to arsenic exposure first became evident as a result of studies done in Taiwan (Smith, A. H., 1997). Epidemiological surveys indicate that three types of epidermic arsenocosis affected areas exist in the mainland of China and Taiwan (Xioying, 1997).

3.5.15 Thailand :

A cohort of subjects with arsenical skin lesions was found assembled in 1987 from a region of environmental arsenic contamination associated with tin mining activities in Ronphibon district of Southern Thailand. In 1996 arsenic is reported to occur in some shallow as well as deep wells in southern Thailand and total affected area is 100 Km^2.

3.5.16 United States:

The USA is probably the only arsenic affected country which has carried out a nation wide survey of arsenic occurrence in drinking water in this country. About 347 000 people had received public supplied water containing more than 50µg/L in this country and about 2.5 million people had received public water supplies containing more than 10µ/L in this country. Small water supplies serving 1,000 to 10,000 persons are contaminated with arsenic exceeding 50µg/L, 10µg/L, and 5µg/L are estimated to be 1% , 7.5% and 13 % respectively in the USA. Arsenic contaminated areas in the USA include about 2,00,000 km^2 in Arizona (As upto 1300µg/L), 5,000 km^2 in California (Arsenic 1 to 2 2600), 1,300 km^2 in Nevada (Arsenic up to 2,600). Studies from 1972 to 1982 showed correlation with specific skin alterations and neurological abnormalities.

3.5.17 Vietnam :

Arsenic in groundwater was first detected in Hanoi in 1997, where arsenic content of 29% of the wells were above 0.05 mg/L. Arsenic contamination of tubewell water has been found in the large deltas of the Mekong and Red rivers in this country. In 1999, UNICEF supported study in 7 Provinces in the Red River Delta reported that 12% samples had shown above 0.05 mg/L arsenic. Groundwater with average arsenic concentration of 430µg/L and maximum arsenic concentration of 3,000µg/L is directly used as drinking water in most affected districts of the country Alarming levels of arsenic in the range of 2,000µg/L to, 3000 µg/L in groundwater were found on both sides of the Red River of this country.

3.6 Problems due to Arsenic Contamination

3.6.1 Arsenic Contamination and Human Health:

The degree of toxicity of arsenic depends on its chemical form and speciation (whether it is organic or inorganic). Water with high level of arsenic leads to various health problems, such as melanosis, lenko-melanosis, hyperkeratosis, black foot disease,' cardiovascular disease, hepatomegaly, neuropathy and cancer. Arsenic accumulates in the liver, kidney, heart and lungs It is also deposited in bones, teeth and hair (Khan, 1997). The toxicity of arsenic depends on the chemical and physical forms of compound, the route by which it enters into the body, the dose and the duration of exposure, dietary compositions of interacting elements and the age and sex of the exposed individuals.

Malnutrition and poor socio economic conditions aggravate the hazards of arsenic toxicity. Although arsenicosis is not an infectious, contagious or hereditary disease, arsenic toxicity creates many social problems for the victims and their families (Khan & Ahmed, 1997).

Toxicity :
According to the various studies and publications, one will die if he or she takes much arsenic. Arsenic is four times poisonous than mercury. The fatal dose of mercury is 500 mg. International Agency for Research on Cancer, considering potential carcinogenicity, has categorized different chemicals having arsenic toxicity into three categories: acute toxicity, sub-acute toxicity and chronic toxicity.

Acute Toxicity :
Acute arsenic poisoning in human being is usually homicidal, suicidal or accidental. Patient first of all complains of a feeling of faintness. nausea and severe burning pain in the throat and stomach. The respirations become labored and lastly convulsion and coma proceeds to death.

Sub Acute Toxicity :
This is a condition where arsenic is administered in a small dose at repeated interval. The symptoms are at first dyspepsia, cough and tingling in the throat, then vomiting and purging with abdominal pain, dry and congested throat and a feeling of depression Patient becomes restless and cannot sleep and gradually results in death.

Chronic Toxicity:
The clinical manifestations due to chronic toxicity develop very insidiously after 6 months to 2 years or more depending on the amount of arsenic intake.

Clinical Manifestations of chronic arsenic Toxicity

Skin Effects:
A number of skin-leisons have been attributed to chronic exposure to arsenic compounds. Hyper pigmentation (melanosis) of the skin is commonly encountered and occurs throughout the body. Melanosis is also observed in tongue and buccal mucus membrane.

Gestro-intestinal Tract (GIT) Effects :

The chronic absorption of arsenic occasionally produces hepatocellular toxicity. Chronic exposure to arsenic has been reported to produce liver enlargement Gastric symptoms like nausea, vomiting, loss of appetite, salvation, constipation or sometimes diarrhea occurs with loss of weight

Renal System effects :

Urine may be colored red or green and some cases, dysuria, anuria (infectious diseases in the renal system) develop.

Cardiovascular System Effects :

Peripheral vascular disease has been observed among persons in Chile and in Taiwan who had chronic exposure to arsenic in drinking water. The changes were associated with hyper pigmentation and hyperkeratosis. Myocardial degeneration and cardiac failure may result from chronic arsenic poisoning.

Nervous System Effects:

Headache, drowsiness, loss of hearing, severe weakness in legs and feet, confusion and convulsion are seen in both acute and chronic intoxication

Respiratory System Effects:

In early stage of arsenic intoxication, respiratory infection is found to be associated with other clinical manifestations

Endocrine System Effects:

Diabetes, Mellitus and Goiter have been reported in association with prolonged ingestion of arsenic through drinking water.

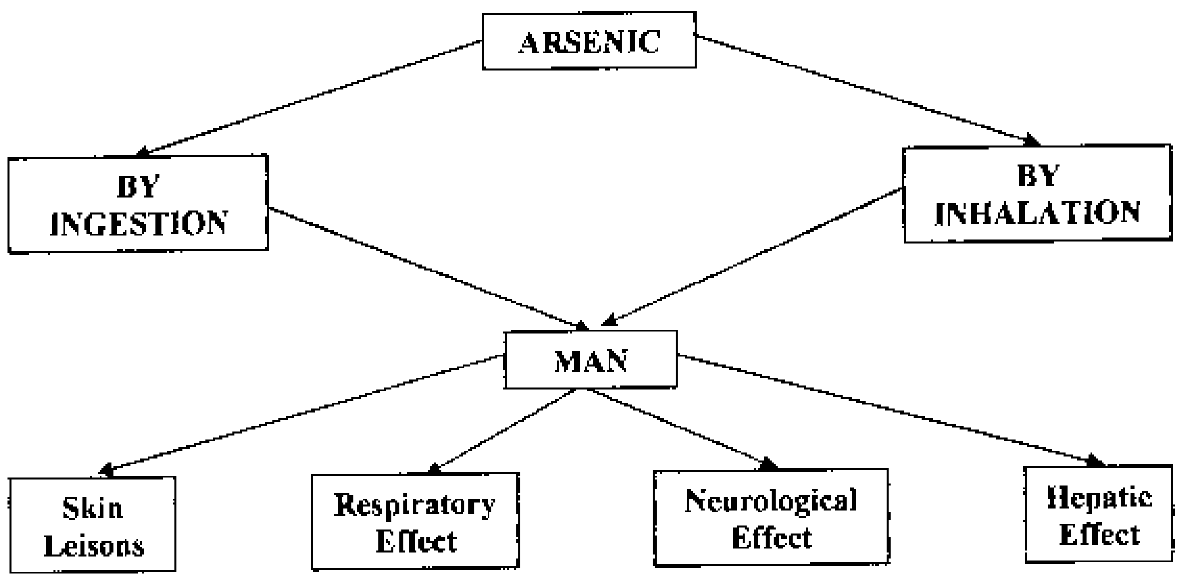
Carcinogenicity :

Arsenic has been found to cause cancer of the skin, liver, lung, urinary bladder, prostate and possibly of lymphatic tissues. Inorganic arsenic may cause lung cancer.

Symptoms of Arsenicosis :

The symptoms of arsenic toxicity may take 8-14 years to be manifested in human body after the patient starts drinking arsenic contaminated water. The period differs from patient to patient depending on the quantity of arsenic ingested, nutritional status of the person, immunity level and the total time of arsenic ingestion. The apparent symptoms of arsenicosis may be said to have manifested themselves as melanosis and keratosis mainly. Darkening of skin (diffuse melanosis) in the body or in the palm is the earliest symptom Spotted pigmentation (spotted melanosis) is usually seen on chest, back or limbs. This is very common symptom. Combination of pigmentation (melanosis) and nodular rough skin (spotted palm planter keratosis) almost points to arsenic toxicity excluding hundreds of causes of isolated pigmentation and nodular rough skin.

Flow Chart 03: Arsenic Effect on Human Body.



Source : Ahmed, S A , 2000, Arsenic, Dhaka.

3.6.2 Social Problems due to Arsenic Effect :

From different findings, it is revealed that a number of social problems arise due to arsenic poisoning of human beings, such as :

1. The affected persons being refused to collect water from the neighbors' tube wells;
2. The affected persons being avoided or disappeared in the public;
3. The affected children being debarred from attending schools, the adults discouraged to attend offices, go shopping and some cases not to visit medical professionals in the hospital etc.
4. With advancement of the disease, patients being rendered incapable of labouring/selling labour and hence victimized by poverty;
5. Affected young women being compelled to stay unmarried;
6. Diseased married women being sent back to their parents with children;
7. Eligible persons are refused jobs when found to be suffering from arsenicosis etc.

CHAPTER: 04

Arsenic Contamination Situation in Bangladesh

4.0 Arsenic Contamination Situation in Bangladesh :

4.1 Causes of Arsenic Contamination :

Earlier several hypotheses were put forward including one that the arsenic compounds were released from the rural electrification poles. These were the sources of arsenic contamination of underground water. Insecticides and fertilizers were also considered as the sources of arsenic to contaminate underground water in this territory. Now it has been more or less generally agreed upon that the source of arsenic contamination is geological with mobilization of arsenic due to some geochemical processes.

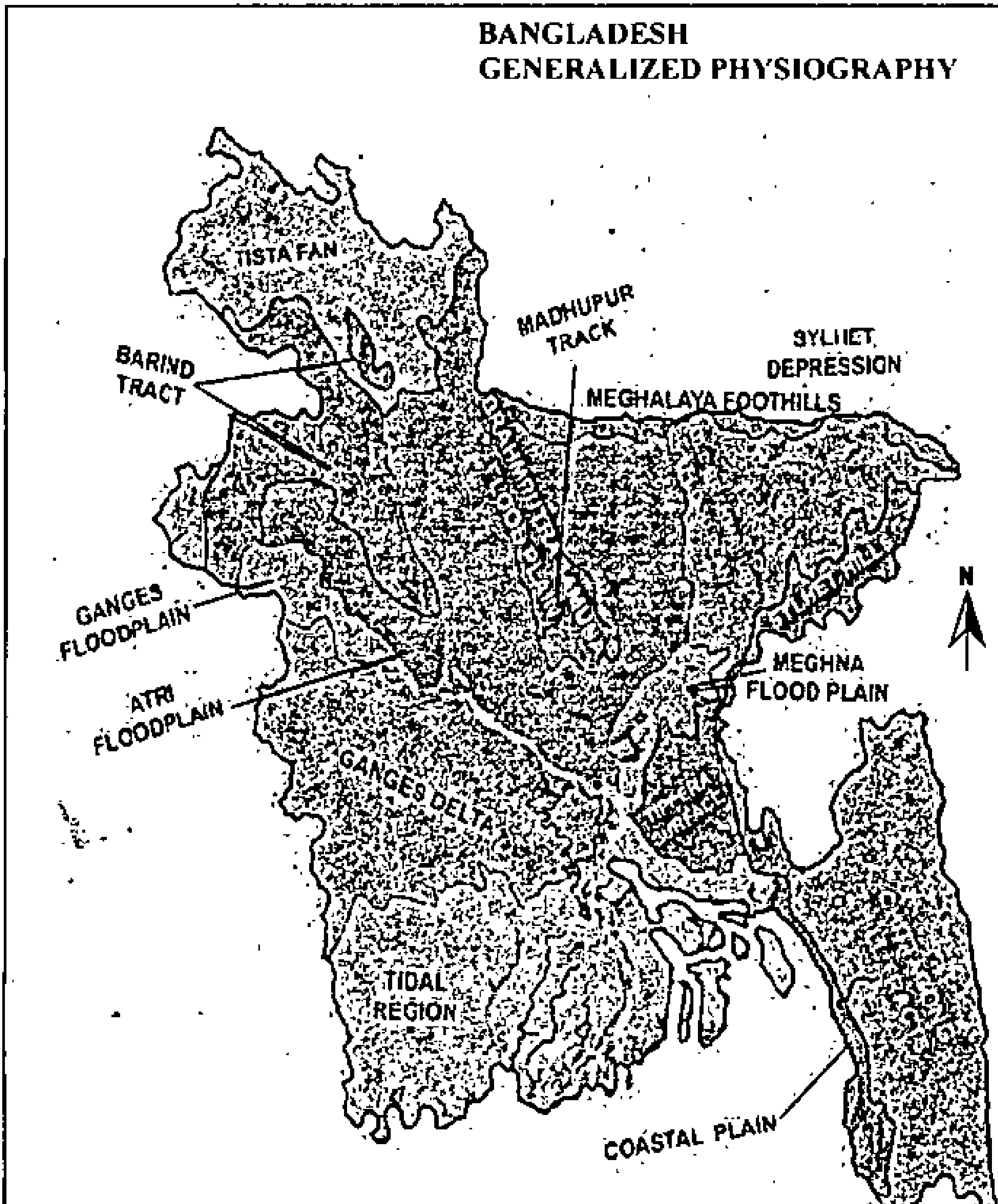
In 1998 study by the British Geological Survey and Mott MacDonald Ltd, found it likely that the arsenic sediment has been released into the groundwater in some areas by a natural process called "Oxyhydroxide Reduction". Thousands of years ago, rocks rich in arsenic were eroded from the Himalayas and other high-lying source areas and deposited along with sands, gravels, silts and clays in low-lying areas those now make up West Bengal, in India and Bangladesh. These arsenic-bearing sediments became buried over thousands of years, forming part of the aquifers we are tapping today for our water resources. As time passed, oxygen levels naturally decreased and under these conditions, the iron and manganese compounds dissolved and released the arsenic into the surrounding water. Thus the origin of arsenic in groundwater is most likely a geological phenomenon.

Geologists cite several other processes by which arsenic can be released into groundwater. The process called "Pyrite Oxidation", for instance, involves iron sulfide compounds which contain arsenic. These compounds dissolve upon contact with oxygen, releasing iron, sulfide and arsenic into the surrounding water. Since there is little or no sulfide in groundwater in Bangladesh, this process is not regarded to be a widespread occurrence in this country.

4.2 Brief History of Tubewells in Bangladesh :

Tubewells are not a new technology in Bangladesh. They are existed in this region during the British colonial era. When partition of India took place, in 1947, there were an estimated 50,000 tubewells in East Pakistan (the former name of Bangladesh). By 1972, the Government had constructed approximately 135,000 tubewells. At this time, there was about one tubewell for every 400 people in Bangladesh.

Map-3



Source : NGO Forum, 2001.

Tubewell was an important source of pathogen-free drinking water in Bangladesh. . Because her surface water was contaminated with bacteria. Drinking untreated or inadequately treated water can cause cholera, dysentery and other water-borne diseases that can be fatal. Where tubewells were not within easy reach, people relied on surface water sources such as ponds. These were usually fenced off and reserved for drinking purposes. In some households the pond water was treated either by adding alum (phitkiri), or by filtering water by passing it through layers of gravel, sand and charcoal in a pot. The more affluent households could afford to have their own dug-wells for drinking water

UNICEF's first major assistance to the water supply in Bangladesh was in response to a devastating cyclone that hit the region in November, 1970; some 10,000 damaged tubewells were repaired. UNICEF continued to assist Bangladesh, initially providing assistance on an emergency food supply program after the end of the War of Liberation, in 1973, and thereafter supporting long term initiatives by the Government to provide safe drinking water.

4.3 Arsenic Occurrences in Bangladesh .

In this subcontinent, at first arsenic pollution was found in West Bengal in 1978 and the symptom of arsenicosis on human bodies was identified at north and south in the district of 24 Pargana. at the same time. In 1983, some arsenic affected people were identified at Barasat by a skin specialist of the School of Tropical Medicine (STM) in India. In 1992 scientists of the School of Environmental Studies (SoES) of Jadavpur University found the symptoms of arsenicosis in the body of a woman of a village of North 24 Paragana. Later on it was known by investigation that this woman had come from a village of Satkhira Zila in Bangladesh. The woman informed that some of her relatives are also affected. The finding has created awareness in Bangladesh about arsenic poisoning (Paul, 1998).

4.4 Extent of the Problem :

At present several departments of the government with assistance from international donor agencies, some NGOs, university departments and private organizations are working on arsenic problem and although there is a lack of standardization in their work (for example, some are using laboratory methods. others are using kits for testing water) and exchange of information among themselves, an overall gloomy picture has emerged. Judging from the scattered reports of many organizations have found unacceptable level of arsenic in ground water from a vast majority of the districts of the country and a large number of patients suffering and dying from arsenicosis and its complications.

Realizing the situation 8065 tubewells from 60 districts have been tested for the presence of arsenic in underground water by Dhaka Community Hospital in collaboration with School of Environmental Studies, Jadavpur University, Calcutta. In 41 districts water samples were found to have arsenic above 0.05 mg/L, the maximum permissible limit, recommended by WHO. In those 41 districts where arsenic concentration crossed 0.05 mg/L limit, 51% of the samples were found to have crossed that border. Area of these 41 districts is 89,186 sq. km with a population of 76.9 million. At the present state of knowledge it can be said that although not all tubewells are contaminated, there are thousands of pockets of contaminated underground water in at least two thirds of the districts of Bangladesh and the people living there are at real risk of developing arsenic toxicosis (Alam, K. 2000).

DCH and SoES conducted surveys for arsenicosis patients in 22 districts and found patients with arsenical skin leisons in 21 of them. They examined 5664 people in the affected villages and 33.6% of them were diagnosed as patients with arsenical skin manifestations. A total of 2167 hair samples, 2165 nail samples, 220 skin samples and 830 urine samples were analyzed and an average of 94% of them were found to have arsenic concentration above the normal limit. A report from the National Institute of Preventive and Social Medicine [NIPSOM] stated that they had more than 800 arsenicosis patients in their list. At the skin department of IPGM&R 250 patients with arsenical skin leisons have been investigated and treated. It is obvious that if systematic surveys are conducted in all the districts where there is high level of arsenic in underground water, more patients will be found.

4.5 Arsenic Situation According to the National Hydro-chemical Survey (2000):

The arsenic contamination situation can also be explained with the statistics from the National Hydro-chemical Survey. The survey was conducted by the Ministry of Local Government, Rural Development and Co-operatives, Department of Public Health Engineering (DPHE) and the British Geological Survey. The survey sampled 3534 tubewells from all over Bangladesh, excluding the Chittagong Hill Tracts (**Table-5**).

According to the National Hydro-chemical Survey Report 2000, arsenic affected areas of the Ganges Delta are vast covering the 54 Zilas out of 64 (Map-3). The areas of these Zilas are about 87,390 sq. km. and the population is about 71 million that is about 50% of the total population of the country (Rahman, M. H., 1997). The biggest arsenic calamity in the world is centered in seven districts of Gangetic West Bengal and adjoining Bangladesh (Dutta, 1997). In 8 districts of West Bengal out of 18, arsenic has been found in groundwater above 0.05 μg/L (mondal, et. al, 1997).

Groundwater arsenic level exceeding the WHO recommended value (0.05 μg/L) have been found in 54 Zilas out of 64 of Bangladesh (The National Hydro-chemical Survey Report, 2000)

Arsenic in shallow tubewell has been detected in almost all districts of Bangladesh. According to the study conducted by the Department of Public Health Engineering (DPHE) and British Geological Survey (BGS), arsenic content of 46 percent of the shallow tubewell water exceeds 0.01 μg/L (WHO Guideline Standard) and that of 27 percent shallow tubewells exceeds 0.05 mg/L (Bangladesh Standard). In the acute arsenic problem areas, more than 90 percent of the shallow tubewells have been found to produce contaminated water exceeding 0.05 mg/L of arsenic. Arsenic content higher than 0.05 mg/L has been reported in about 2 percent of shallow tubewell water in Bangladesh. Due to this, more than 7000 arsenicosis patient have so far been identified in arsenic affected areas in Bangladesh (Rahman, et. al, 2000).

Table-5 : Arsenic Statistics from the National Hydro-chemical Survey

By Concentration	Number	% Tubewell	Avg. concentration (μg/L)
<10μg/L	2045	58	2
10-50 μg/L	606	17	25
50-200 μg/L	566	16	103
>200 μg/L	317	9	372
Total	3534	100	55

Source : National Hydro-chemical Survey, 2000.

The survey showed that 25% of the tubewells sample contained in excess of 50 μg/L arsenic (the Bangladesh drinking water standard) and 9% of the tubewells exceeded 200 μg/L **(Table-6).**

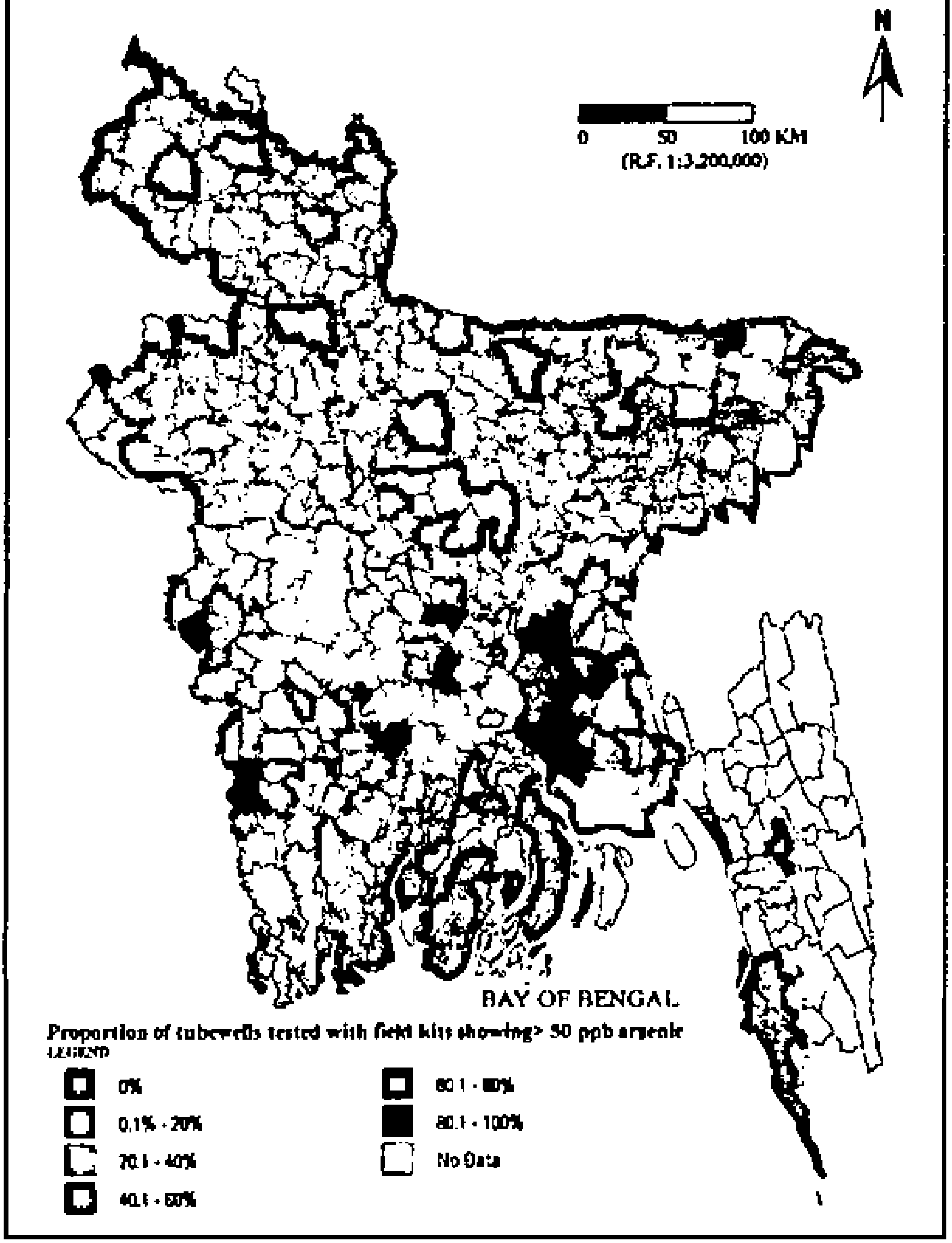
Table-6: Arsenic Statistics from the National Hydro-chemical Survey, (2000).

Tubewell	**By Depth**	**Number**	**% Tubewell**	**Avg. concentration (μg/L)**
Shallow tubewell	<15m	287	8	58
	15-30m	1180	33	76
	30-60m	1258	36	56
	60-90m	317	9	33
	90-150m	165	5	45
Deep tubewell	150-200m	32	1	7
	200m	295	8	3
	Total	**3534**	**100**	**55**

Source: National Hydro-chemical Survey, 2000

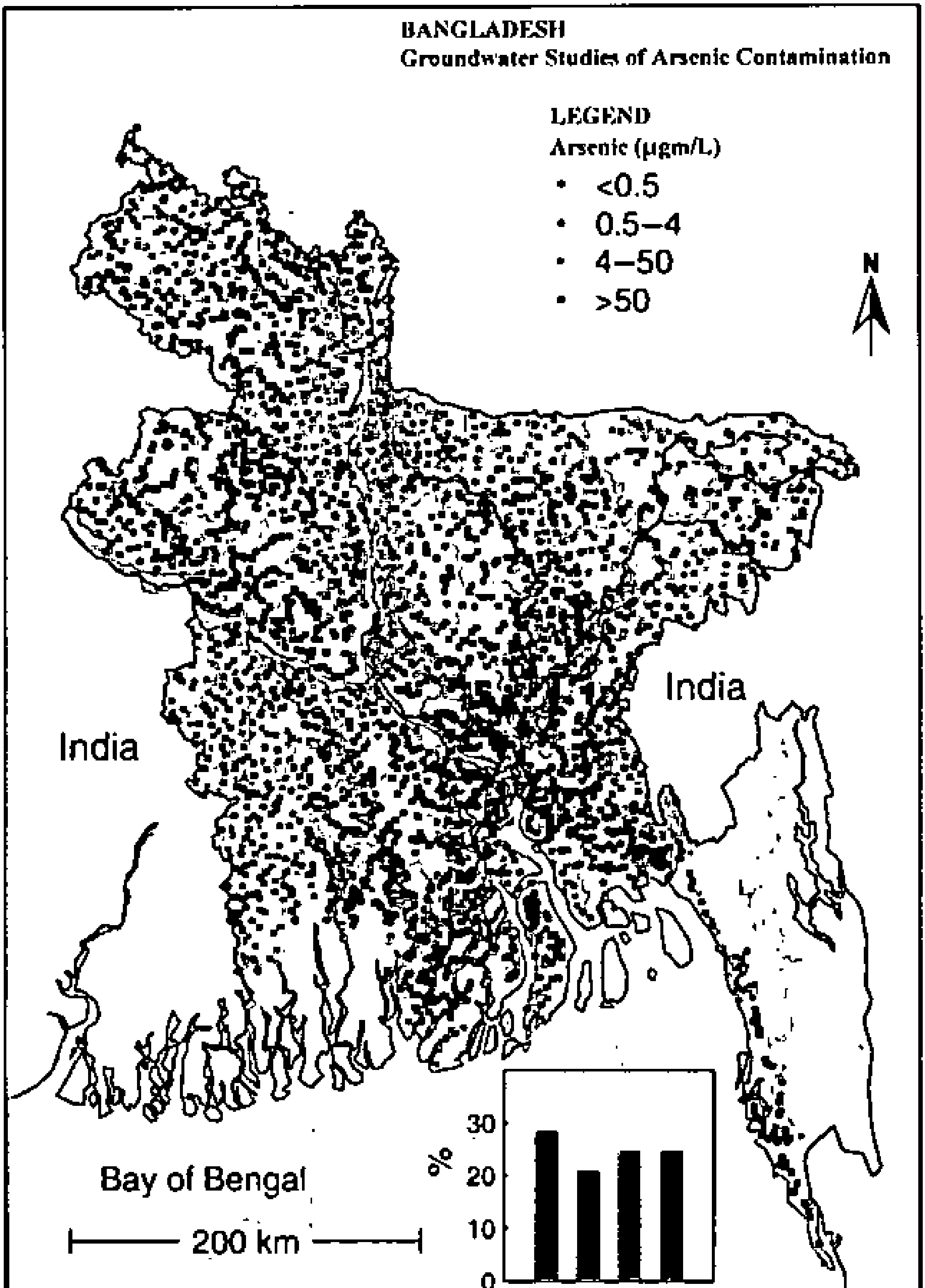
Map-4

ARSENIC CONTAMINATION IN BANGLADESH



Source : DPHE, 1999.

Map-5



Source : DPHE, 2000.

The maximum concentration of arsenic (76µg/L) is found in 33% of shallow tubewell within 15 to 30 m depth. On the other hand, minimum concentration (33µg/L) is found in 9% shallow tubewells within 60-90 m depth **(Table- 6).** In case of deep tubewell, maximum concentration of arsenic (7µg/L) is detected in 32 tubewells within 150-200 m depths **(Table- 6).** Moreover 54 Zilas out of 64 have found arsenic in tubewell water at more than permissible level **(Table-7).**

Table-7 : Compliance with Bangladesh Standard (50 µg/L)

	Number		
	<50µg/L	>50µg/L	Total
Divisions	0	6	6
zila	8	54	61
Upazila	184	249	433

Source: National Hydro-chemical Survey, 2000

Table-8 : Compliance with Bangladesh Standard (10µg/L)

	Number			%		
	<10 µg/L	>10µg/L	TOTAL	<10µg/L	>10µg/L	TOTAL
Divisions	0	6	6	0	100	100
zila	8	53	61	13	87	100
Upazils	39	394	433	9	91	100

Source : National Hydro-chemical Survey, 2000

The findings on 'Groundwater Studies of Arsenic Contamination in Bangladesh' conducted by Ministry of Local Government, Rural Development and Cooperatives, Government of Bangladesh (2000) are as follows :

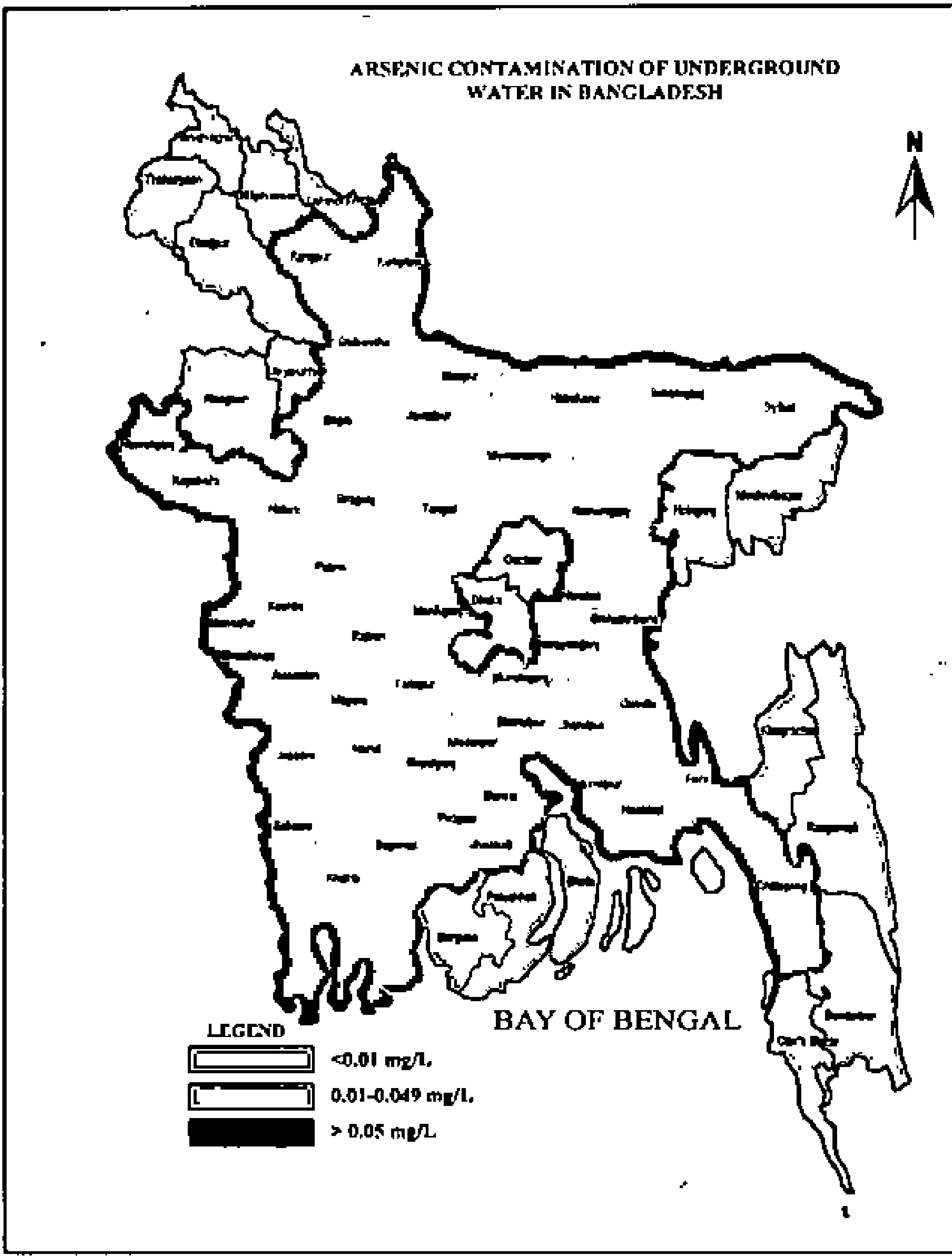
- All Zilas except Thakurgaon had at least one tubewell exceeding the WHO standard;
- The minimum arsenic concentration was found below 1µg/L which is mostly common in northern parts of Bangladesh.
- The population exposed to arsenic from water exceeding the Bangladesh standard was estimated 30 million (Upazila-average). This is based on an estimated 1999 population (of 125.5 million for the whole of Bangladesh as projected from the 1991 census data).
- Few groundwater from the South of the country were arsenic-free (i.e. with less than .05µg/L).
- 54 of the 61 districts sample had at least one well with water exceeding 50µg/L. The worst affected districts were: Chandpur (90%), Munshigonj (83%), Gopalgonj (79%), Madaripur (69%), Noakhali (69%), Satkhira (67%), Comilla (65%), Faridpur (65%) Shariatpur (65%), Meherpur (60%), Bagerhat (60%) and Lakshmipur (56%). (Ahmed. S. A., 2000)
- The least affected districts were Thakurgaon, Patuakhli, Panchagarh, Nilphamari, Natore, Lalmonirhat, Borguna, (all 0%), Rangpur (1%), Dinajpur (2%), Naogaon (2%), Gazipur (2%). Cox's Bazar (2%), Bhola (4%), Nawabganj (4%), Jhalakati (6%), Rajshahi (6%), Gaibandha (7%), Tangail (9%) and Kurigram (9%) (Ahmed, S. A , 2000).

Table-9 : Percentage of wells in Different Arsenic Concentration Ranges in Bangladesh

Districts	Arsenic Concentration Range					
	<10	10-50	50-200	>200	>50	N
Bagerhat	19	21	31	29	60	100
Barguna	97	3	0	0	0	100
Barisal	58	12	12	18	30	100
Bhola	96	0	2	2	4	100
Bogra	77	15	2	2	4	100
Bragamanbaria	51	9	17	23	40	100
Chandpur	8	2	10	80	90	100
Chittagong	68	16	11	5	16	100
Chuadanga	18	34	38	6	44	100
Comilla	29	5	37	28	65	100
Cox's Bazar	95	2	2	0	2	100
Dhaka	58	11	27	4	31	100
Dinajpur	95	3	2	0	2	100
Faridpur	24	11	35	30	65	100
Feni	47	21	26	6	32	100
Gaibandha	66	27	6	1	7	100
Gazipur	98	0	2	0	2	100
Gopalgonj	17	5	43	36	79	100
Habigonj	47	42	8	2	10	100
Jaipurhat	98	3	0	0	0	100
Jamalpur	68	25	5	2	6	100
Jessore	29	23	41	7	48	100
Jhalakati	79	18	3	3	6	100
Jhenaidah	37	37	22	4	26	100
Khulna	62	16	20	2	22	100
Kishorgonj	41	32	21	6	27	100
Kurigram	62	29	8	1	9	100
Kustia	60	13	17	11	28	100
Lakshmipur	24	21	26	29	56	100
Lalmonirhat	97	3	0	0	0	100
Madaripur	31	0	31	39	69	100
Magura	63	19	16	3	19	100
Manikgonj	36	49	15	0	15	100
Maulavibazar	62	26	9	2	11	100
Meherpur	7	33	40	20	60	100
Munshigonj	36	49	15	0	15	100
Mymensingh	75	12	13	0	13	100
Naogaon	95	3	1	1	2	100
Narail	38	21	25	17	42	100
Narayanganj	70	7	13	10	23	100
Netrokona	43	29	25	3	28	100
Nilphamari	94	6	0	0	0	100
Noakhali	16	14	37	33	69	100
Pabna	74	9	10	6	17	100
Panchagarh	95	5	0	0	0	100
Patuakhali	93	7	0	0	0	100
Pirojpur	66	17	11	6	17	100
Rajbari	53	24	15	9	24	100
Rajshahi	82	12	6	0	6	100
Rangpur	84	15	0	1	1	100
Shatkhira	18	15	41	26	67	100
Shariatpur	24	10	35	31	65	100
Sherpur	55	33	12	0	12	100
Shirajgonj	42	35	22	1	24	100
Shunamgonj	15	44	38	3	41	100
Sylhet	55	27	18	0	18	100
Tangail	55	36	9	0	9	100
Thakurgaon	100	0	0	0	0	100
TOTAL	**58**	**17**	**16**	**9**	**25**	**100**

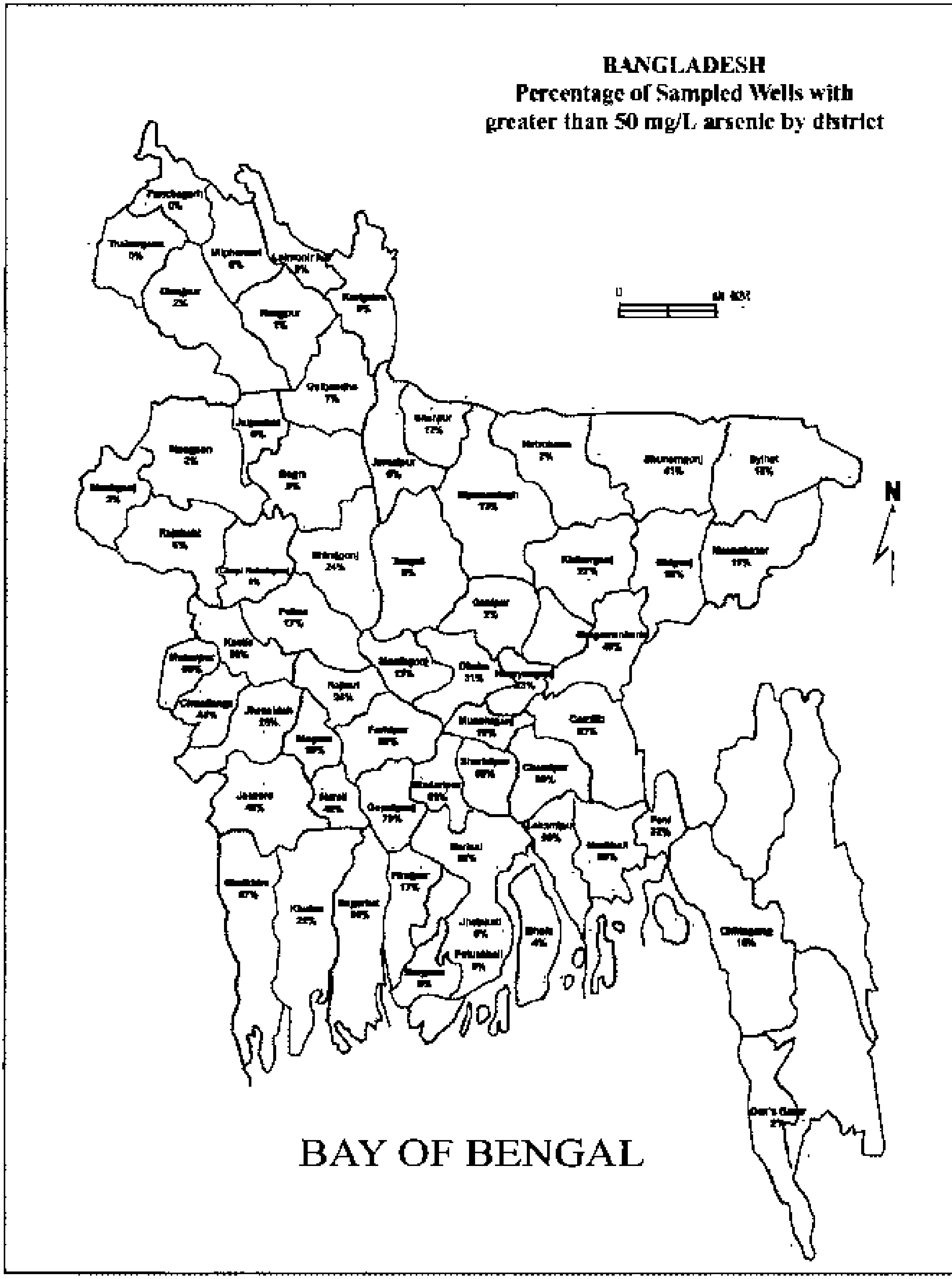
Source: Ministry of Local Government, Rural Development and Co-operatives, Government of Bangladesh (2000), Groundwater Studies for Arsenic Contamination in Bangladesh.

Map-6



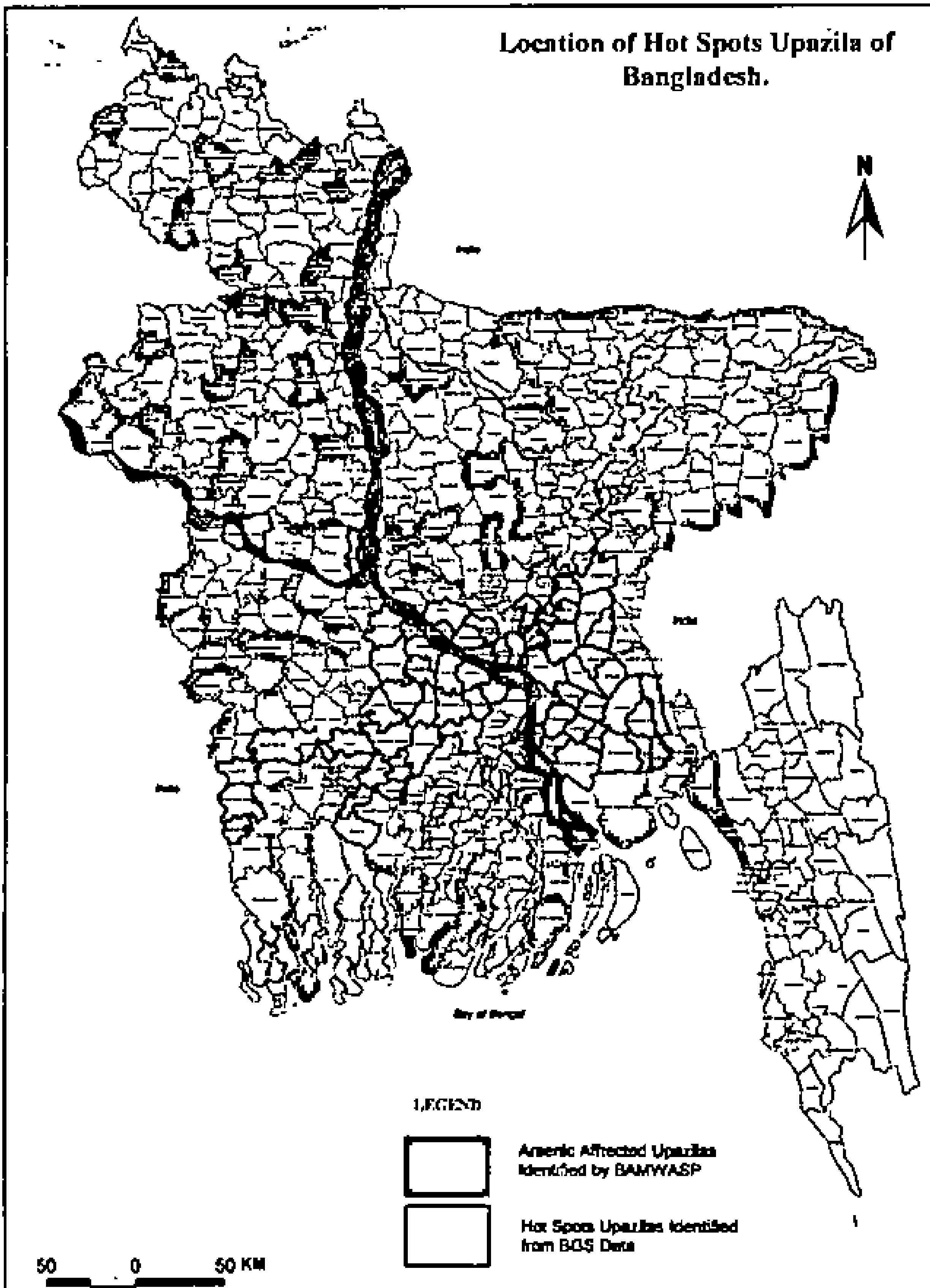
Source : NGO Forum, 2001.

Map-7



Source : DPHE. 2000.

Map-8



Location of Hot Spots Upazila of Bangladesh.

Source : DPHE, 2001

4.6 Field Test Kits :

The scale of arsenic contamination and the need for providing feedback to users of water has led to the development of field testing kits by various agencies. DPHE and NGO's carried out more than 35,000 field tests in a six months period. UNICEF is supporting DPHE to promote a consistent way to label wells as safe or unsafe, by painting them green and red, respectively, after testing.

UNICEF is also cooperating with a World Bank-funded Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) that is expected to screen tubewells in all 460 Thanas of the country.

UNICEF has procured an interim field test kit known as the MERCK kit, manufactured in Germany. About 2,000 kits have been distributed among the NGO partners for immediate deployment in the field 660 kits to BRAC, 410 to Grameen Bank, 240 to Dhaka Community Hospital and 300 to the Rotary Club. Results from the field show that the MERCK kit is relatively reliable in indicating whether the water sample has arsenic below 20 ppb or above 100 ppb. To be on the safe side, tubewells that contain arsenic between 20-25 ppb are also being marked as red or as unsafe.

NEERI (1998) has carried out a detailed comparison of five kits both in the field and in the laboratory on behalf of WHO. UNICEF (1998) carried out a more limited evaluation of field test kits. The five kits tested by NEERI were:

i) Asian Arsenic Network (AAN) kit from Japan: The kit is semi-quantitative; it claims a detection range of between 0.02 and 0.7 mg/L and costs about Tk. 1690.

ii) Merck kit from Germany : This is also semi-quantitative; it claims a detection limit of 0 1 gm/L and cost Tk. 3,200 in the local market.

iii) Aqua kit . The qualitative kit was developed in Calcutta for UNICEF and subsequently put into commercial production there. The kit claims a detection limit of 0.05 mg/L and costs about Tk. 2000

iv) NIPSOM kit: A locally produced modification of the AAN kit. It costs about Tk 1000.

v) AIIH & PH kit produced by the All India Institute of Hygiene and Public Health. It is an improvement of the UNICEF/Aqua kit, also with a detection limit of 0.05 mg/L and probable cost of Tk. 840.

4.7 Efforts in Mitigation of Arsenic Disaster:

Since 1996 different organizations including the government, NGOs and private organizations have come forward to study different aspects of the arsenic problem and find out ways of combating against it. The government has formed a National Steering Committee with the Minister of Health and Family Welfare as its chairman. Other government bodies involved in the arsenic work are : Ministry of Local Government, Rural Development and Co-operatives, Ministry of Health and Family Welfare (MoH&FW), Economic Relations Division of the Ministry of Finance & Planning Commission, Environmental and Geographic Information System (EGIS) for Water Resources Planning, National Institute of Preventive, Social and Occupational Medicine (NIPSOM), Department of Public Health Engineering (DPHE),and Institute of Postgraduate Medicine and Research (IGM&R). International donor agencies have shown their interest in the arsenic problem The UNDP has funded a Rapid Action Program (RAP) which has currently being implemented jointly by the Ministry of Health and Family Welfare and Dhaka Community Hospital (DCH) in 200 villages of the arsenic affected districts. The UNICEF has provided field test kits to DPHE. WHO invited arsenic experts to this country to work on the arsenic problem in Bangladesh Foreign missions like the Department of Foreign International Development (DfID) Japanese International Co-operation Agency (JICA), Denish International Development Agency (DANIDA), Canadian Intrigated Development Agency (CIDA) and the Netherlands have shown their willingness to take part in the fight against arsenic. Asia Arsenic Network (AAN) is actually running a project in Samta, a remote village in the western part of the country.

4.8 Role of Organizations to Combat Arsenic Problem

4.8.1 Role of Government Organizations:

Two surveys are being carried out with assistance of UNICEF and the British Government. The Project was launched in July 1994 with the sponsorship of World Bank

4.8.1.a. Arsenic Mitigation Project, Ministry of Health and Family Welfare:

They surveyed the level of contamination in deep tubewell water of two hundred villages in 43 Thanas of 21 Zilas. They identified 1082 patients having been affected by arsenic (according to NIPSOM this number is 1593). Among them, 991 are men, 648 are women and the rest are children, 19,787 tubewells out of 32,651 in these two hundred villages were found having an excess amount of arsenic.

4.8.1.b. Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), Directorate of Public Health :

It has conducted tests of tubewell water in the laboratories in Khulna, Rajshahi, Comilla and Mymensingh. A key component of the BAMWSP will be the use of community based demand driven projects, in which community members play an active role in choosing and implementing solutions to the site-specific problems of arsenic contamination. The findings up to the month of June 1998 showed that·

Number of tubewells Total examined	:	24,964
Number of tubewells contaminated by arsenic	:	5,333(21%)

4.8.1.c. Department of Public Health Engineering (DPHE)

Department of Public Health Engineering (DPHE) initiated monitoring and water testing activities in the adjacent border Zilas in 1993.

DPHE under a Technical Assistance Project procured 500 arsenic test field kits distributed to Zila and Upazila level. Till January 1998 a total number of 19,167 samples from hand pump tubewells have been tested by field test kits covering almost the whole country where 3,731 samples have showed positive result.

DPHE is providing various alternate options of safe drinking water to the peoples of arsenic affected areas and also conducting various research and development activities to mitigate the problem.

According to DPHE, alternate water supply options in arsenic contaminated areas are as follows:

1. Deep Tubewell (Hand pump).
2. Pond water with sand filtration (PSF).
3. Sanitary Ring Well (SRW)
4. Rain Water Harvesting (RWH).
5. Surface water treatment for Urban centers etc.

4.8.2 Role Of NGOs :

The following NGOs have taken initiatives to mitigate the arsenic contamination in drinking water of Bangladesh

4.8.2.a. Bangladesh Rural Advancement Committee (BRAC) :

BRAC has initiated some programs on arsenic. As a first step, BRAC initiated two testing programs. The intensive one tested all the tubewells of one Thana, where according to previous information, the problem was said to be worse. The water-testing program initiated by BRAC was implemented in collaboration with the DPHE Water test is a vital program of BRAC and Hajigonj in Chandpur district was an extensive working area of BRAC **(Table-10).**

Table-10 : Survey Report by BRAC on Hajigonj Tubewells at a Glance, 1997.

Total Population of the Thana	2,54,057
Number of Unions	11
Number of Villages	156
Number of tubewells tested by field kits	111954
Number of tubewells contaminated with arsenic	11,095 (93%)
Number of villages with all tubewells contamination	83(53%)
Number of samples tested by spectrophotometer	193
Field test results confirmed by spectrophotometer (% cases)	92

Source. BRAC, 1997.

BRAC is working in collaboration with UNICEF/DPHE and actively involve in community assessing and mitigating the arsenic situation. It has launched projects entitled 'Community Based Arsenic Response Project' in September 1998 and 'Action Research on Community Based Arsenic Mitigation Project' in June 1999. It has worked under the Action Research Project on Sonargaon Thana of Narayangonj Zila and on Jhikorgacha Thana of Jessore Zila.

Table11 : Test Results at a Glance

Parameters	**Jhikorgacha**	**Sonargaon**
Total tubewells	2135	1190
Tubewell painted red ($\geq$0.05µg/L)	756	729
Tubewell painted green (<0.05µg/L)	1379	416
Total % of red marked tubewells	35	61
Total % green marked tubewells	65	39

Source: Interim Report, June-October 1999, BRAC.

The Project has selected the following alternative safe water options for the above mentioned arsenic affected areas: (a) Rain Water Harvesting (RWH), (b) Pond Sand Filter (PSF), (c) Dug well & (d) Safi Filter etc. According to BRAC, all these alternative safe water options are not feasible for every place or for every class of people in society. Therefore, it is required to evaluate the viability, effectiveness and the acceptability of different water options.

4.8.2.b. OXFAM:

OXFAM is conducting its activities with a view to growing pubic awareness on using safe water and its management. OXFAM has carried out surveys and presented demonstration in various workshops regarding how water can be purified from arsenic. It has also provided the Calamity Prevention Forum with monetary assistance in making a videocassette concerning the arsenic issue. The Forum has published a booklet with the financial aid from OXFAM on different sources of safe and clean water. On courtesy of OXFAM, several enjoyable but very brief programs have been broad custed both on TV and Radio to make the people familiar with the arsenic problem, to make them active to set up alternative safe water options and to give lessens about the uses of water from both contaminated tube wells and from natural sources.

4.8.2.c. Dhaka Community Hospital (DCH):

Dhaka Community Hospital (DCH) has launched so many programs from 1993 in relation to arsenic problem in Bangladesh. Its programs and achievements are given below in brief:

DCH Arsenic Activities
(Period till Sept 1999.)

1.	Number of Zilas surveyed	:	64
2.	Number of Upazilas covered for water	:	200
3.	Number of village covered for water	:	1,200
4.	Nos. of TW samples collected	:	15,000
5.	Nos. of sample more than 0.01 ppm	:	61.9%
6.	Nos. of sample more than 0.05 ppm	:	45.6%
7.	Total hair samples collected at toxic level.	: :	3,342 (89%)
8.	Total nail samples collected at toxic level	: :	3,46 (98%)
9.	Total skin samples collected at toxic level.	: :	373 (100%)
10.	Total Urine samples collected at toxic level, average	: :	1,043 (92%)
11.	Number of patients identified	:	2,700
12	Number of Zilas surveyed for pts.	:	28
13.	Number of TW found contaminated (Arsenic content <0. 0 1 ppm.)	:	16.05%
14.	Nos. Zilas having As. Conc. >0.05 ppm	:	42 districts
15.	Area of these Zilas.	:	89,186 sq. km.
16.	Population of these Zilas	:	76.9 million.
17.	Developing community based Mitigation Model	:	70 centers
18.	An Action Research on Community based Arsenic Mitigation Program (With DCH-DPHE-UNICEF)	:	In One Upazila
19.	National Emergency Screening Program (BAMWASP) Under BAMWSP providing Training to Field Workers working in the field emergency arsenic mitigation program	:	One Upazial
20.	Developing DCH Model for arsenic mitigation in community by UNICEF and other agencies	:	In 3 Villages
21.	Testing water by field kit of Merck and arsenator	:	At field level
22.	Organizing Conf. arranging media coverage and taking part in arsenic related propagandas	: :	Nationally and Internationally

Source: DCH, 2000.

As a private organization, Dhaka Community Hospital has been involved in the alleviation of the arsenic problem from the very beginning. It has conducted extensive surveys, supporting treatment of patients, training programs for doctors and other health and community workers and awareness programs Recently DCH is engaged in implementing the Rapid Action Program in collaboration with the Ministry of Health and Family Welfare

Dhaka Community Hospital (DCH) Arsenic Programs :

At present Dhaka Community Hospital (DCH) is deeply involved with the arsenic problem in Bangladesh.

1. Already implemented a survey including 20,000 samples of water, hair, nail, skin and urine test in 64 districts with water contaminated by arsenic and finding arsenicosis cases due to arsenic poisoning in collaboration with Dr. Dipanker Chakraborti of Jadavpur University of India
2. An international seminar on arsenic was organized, 8-12 Feb 1998.
3. A national seminar on arsenic was organized, 6 January 1997.
4. House to house survey is going on in 500 villages on arsenic contamination.
5. National and International media coverage to increase global and local community awareness.
6. Working to establish a laboratory (for environmental health hazards) and out patient clinics for arsenicosis
7. Training doctors, paramedics and health workers for arsenic mitigation.
8. DCH has identified more than 4,000 arsenic-related patients. DCH has established 7 rural arsenic clinics in the affected areas and has established an arsenic referral clinic in Dhaka.
9. DCH is conducting Emergency Arsenic Mitigation Programs in 500 villages in different districts of Bangladesh

4.8.2.d. National Institute of Preventive, Social and Occupational Medicine (NIPSOM)

NIPSOM has tested tubewell water and found 44 arsenic affected Zilas out of 64 Zila in Bangladesh. The affected Zilas are as follows:

Bagerhat, Borguna, Barisal, Bhola, Bogra, Bragamanbaria, Chandpur, Chittagong, Chuadanga, Comilla, Cox's Bazar, Dhaka, Dinajpur, Faridpur, Feni, Gaibandha, Gazipur, Gopalgonj, Habigonj, Jaipurhat, Jamalpur, Jessore, Jhalakati, Jhenaidah, Khulna, Kishorgonj, Kurigram, Kustia, Lakshmipur, Lalmonirhat, Madaripur, Magura, Manikgonj, Maulavibazar, Meherpur, Munshigonj, Mymensingh, Naogaon, Narail, Narayangonj, Netrokona, Nilphamari, Noakhali, Pabna, Panchagar, Patuakhali, Pirojpur, Rajbari, Rajshahi and Rangpur.

4.8.2.e. UNICEF :

UNICEF has also played a vital role in arsenic mitigation through its various programs in collaboration with DPHE, BRAC, Grameen Bank etc. Basically UNICEF provides financial help and technical assistance in water test, training and other mitigation initiatives. The major programs of UNICEF in relation to arsenic problem are as follows :

UNICEF - DPHE National Testing Program : Analyzed about 30,000 tests up to Jan. 10, 1999.
UNICEF - BRAC Testing Program : Covered appox. 14,000 tubewells.
UNICEF - Grameen Bank Testing Program : Covered appox. 2,000 tubewells.
UNICEF - also supported procurement of lab supplies and training to build capacity of labs.

UNICEF became aware of presence of arsenic in groundwater when informed by WHO in late 1994 that arsenic contamination was suspected in certain districts along the West Bengal border in Bangladesh. A Technical Assistance Project Proposal (TAPP) for a "Study in Arsenic Affected Areas in Bangladesh" with UNICEF assistance to DPHE was initiated in 1995 and approved in 1996 Since 1996, UNICEF has been providing technical assistance to DPHE to conduct a nationwide sample survey to determine the magnitude and extent of the problem. UNICEF was the first international agency to fund such large-scale water sample testing. Arsenic testing is now part of the standard testing protocol, jointly developed and adopted by DPHE and UNICEF and is now done prior to all public installation of tubewells in the country. UNICEF, since the mid- 1990 , has been working with the Government of Bangladesh and NGOs to first gain a better understanding of the extent of the problem and to find viable community based integrated arsenic mitigation approaches that will provide the basis for scaling up in affected areas.

UNICEF is supporting activities on both national and local levels. The national program includes the ongoing national testing program, provision of alternative safe water sources in 29 underserved, flood-affected and arsenic-affected districts, as well as survey to identity arsenic-affected patients. With regard to the local initiative in four Thanas, covering about 500 villages, UNICEF, in cooperation with DPHE, has entered into partnership agreements with the Bangladesh Rural Advancement Committee (BRAC), Dhaka Community Hospital and the Grameen Bank UNICEF will also be supporting the Dhaka Community Hospital (DCH), in training medical doctors and village level workers on the techniques of arsenic testing and patient identification. UNICEF contributes financial, technical and other assistance to the safe water supply and other programs. In conclusion, as partners in the national rural water supply and sanitation program over the last 27 years, the Government of Bangladesh and UNICEF are committed to participate fully in efforts to combat the threat, and mitigate the effects of pathogens, arsenic and other contaminants in drinking water of Bangladesh.

4.8.2.f. The World Bank :

According to the agreement between World Bank and Bangladesh signed on 21st September, 1998, World Bank will give Bangladesh US$ 32.4 million to mitigate the arsenic contamination problem in drinking water of Bangladesh.

4.8.2.g. NGO Forum :

NGO Forum started detecting the presence of arsenic in ground water through its regional offices since October 1997. It has tested 10797 water samples so far with the help of available field testing kit. Out of this total number of tested samples, 2548 were found arsenic contaminated. All these tests were conducted in 2882 villages in 257 Thanas of 58 districts Out of those tests 782 villages were found having arsenic above the permissible limit. NGO forum has been maintaining close collaboration with relevant government agencies (DPHE, NIPSOM, LGED etc.), Universities, UN bodies (UNICEF, World Bank etc.), Donors, DPHE-DANIDA, Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) as well as with other NGOs in relation to arsenic by sharing findings of its field level interventions

NGO Forum is playing a vital role in Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) as a member of the steering committee as well as also in the implementation of the project including selection of partner NGOs and CBOs for implementation in the selected area. NGO Forum has developed and produced two posters and two leaflets on arsenic issue NGO Forum has been disseminating research oriented information relating to arsenic and arsenicosis through its monthly Bangla newsletter titled "PANI PRABAHO" and quarterly English newsletter "WATSAN". NGO Forum is providing alternate water options including DANIDA's Bucket Treatment Unit (BTU), Rainwater Harvesting System, Pond Sand Filter, Dug Well, etc to the arsenic affected community. Recently NGO Forum offered training services to BAMWSP for its 'Emergency Screening and Arsenicosis Patients Identification' program involving community people at Singair Thana of Manikganj District.

In brief the following authorities have taken part in different aspects of mitigating the arsenic contamination problem in tubewell water in Bangladesh:

- School of Environmental Studies (SoES), Jadavpur University, Calcutta;
- Department of Geology, Calcutta University, Calcutta;

- Department of Geological Sciences, University College, London;
- British Geological Survey (BGS), London;
- UNICEF, Dhaka;
- World Health Organization (WHO), Dhaka;
- Regional Water Supply & Sanitation Group (RWSSG), World Bank, Dhaka;
- Department of Geology, Dhaka University, Dhaka;
- Department of Geology, Rajshahi University, Rajshahi;
- Department of Chemistry, Jahangirnagar University, Savar;
- Bangladesh University of Engineering and Technology (BUET), Dhaka;
- International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), Dhaka;
- NGO Forum, Dhaka;
- Department of Public Health Engineering (DPHE), Dhaka;
- Dhaka Community Hospital (DCH), Dhaka;
- Bangladesh Rural Advancement Committee (BRAC), Dhaka,
- National Institute of Preventive, Social and Occupational Medicine (NIPSOM), Dhaka.

4.9 Alternative Sources of Safe Drinking Water in the Arsenic Affected Areas :

Principle of developing arsenic free alternative water options:

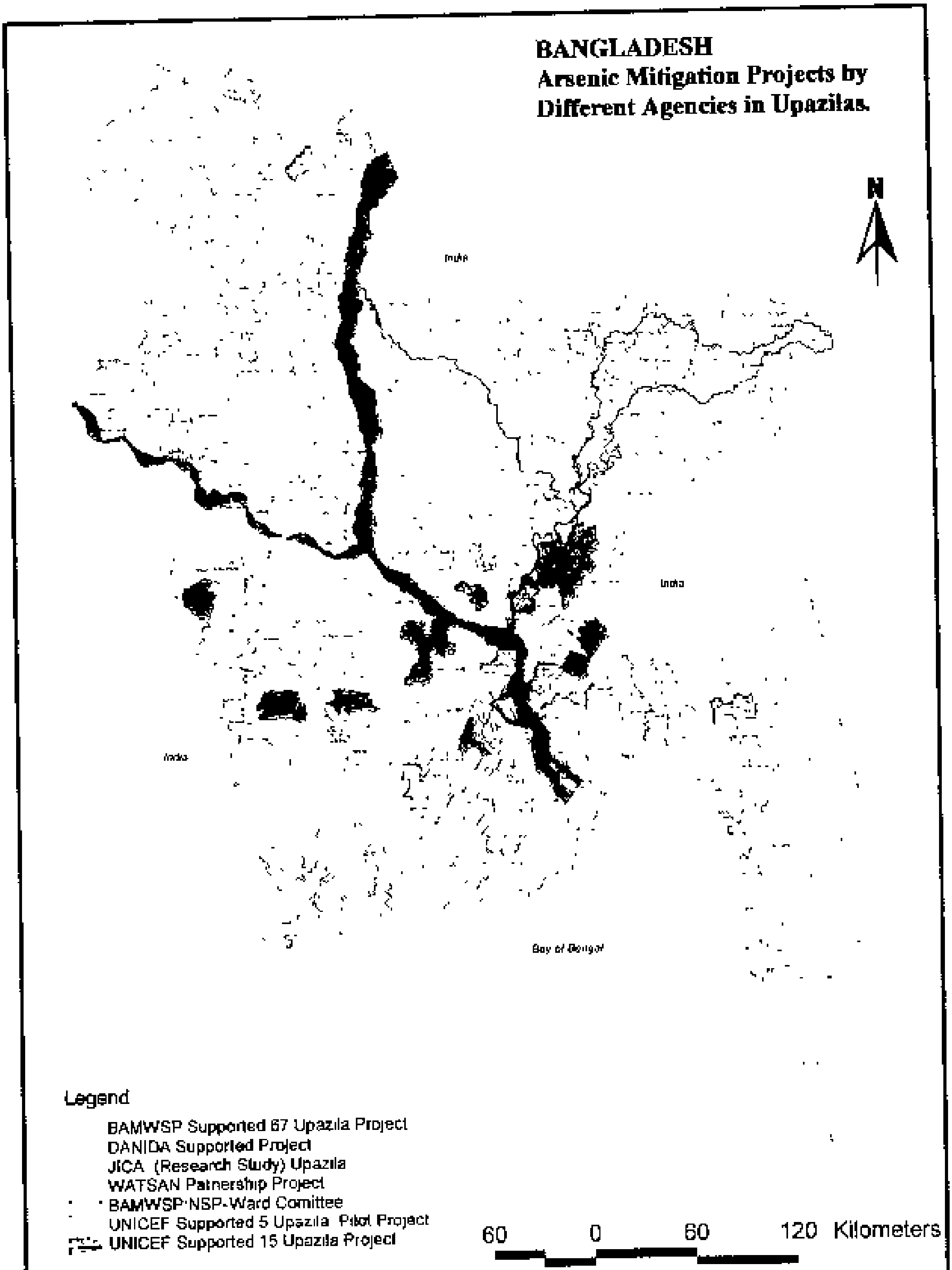
1. **By avoiding arsenic contaminated water:** By using of naturally arsenic-free water (i.e. surface water, ground water and rain water).

2. **By treating arsenic contaminated tubewell water:** Arsenic contaminated water has been treated in two ways: by using chemicals and by using natural material (sand, iron and charcoal).

An estimated 29 million people exposed to arsenic contaminated water exceeding Bangladesh standard will urgently require arsenic safe water supply. A shift from shallow tubewells to alternative water supply options has become essential in acute arsenic problem areas (Ahmed, F M., 2000). Alternative water supply options include:

- Groundwater from alternative arsenic-safe aquifers
- Treatment of surface water
- Rainwater Harvesting

Map-9



Source : DPHE, 2001.

4.9.1 Groundwater:

Technological Options :

Suitability of hand-pump technology depends on groundwater level, water quality and hydro-geological conditions of the area. Arsenic safe groundwater is generally found in shallow aquifers in north-western region. Deep aquifers separated from shallow contaminated aquifers by impermeable layers can be a dependable source of arsenic safe water The important alternative water supply technologies include :

- Shallow shrouded tubewell (SST) and Very shallow shrouded tubewell (VSST);
- Deep Tubewell;
- Infiltration galley

4.9.1.a. Shallow shrouded Tubewell (SST) and Very shallow shrouded Tubewell (VSST)

In many areas, groundwater with low arsenic content is available in shallow aquifers To get water through these aquifers, an artificial sand packing is required around the screen of the tubewell. This artificial sand packing, called shrouding.

These low-cost hand-pump tubewell technologies have been designed and installed in the coastal areas to collect water from very shallow aquifers. The SST/VSSTs can be convenient methods for withdrawal of fresh water in limited quantities. The systems may be considered suitable for drinking water supply for small settlements. The department of Public Health Engineering has sunk a total of 5,904 VSST/SST to provide water to 0.44 million people in coastal areas (DPHE, 2000).

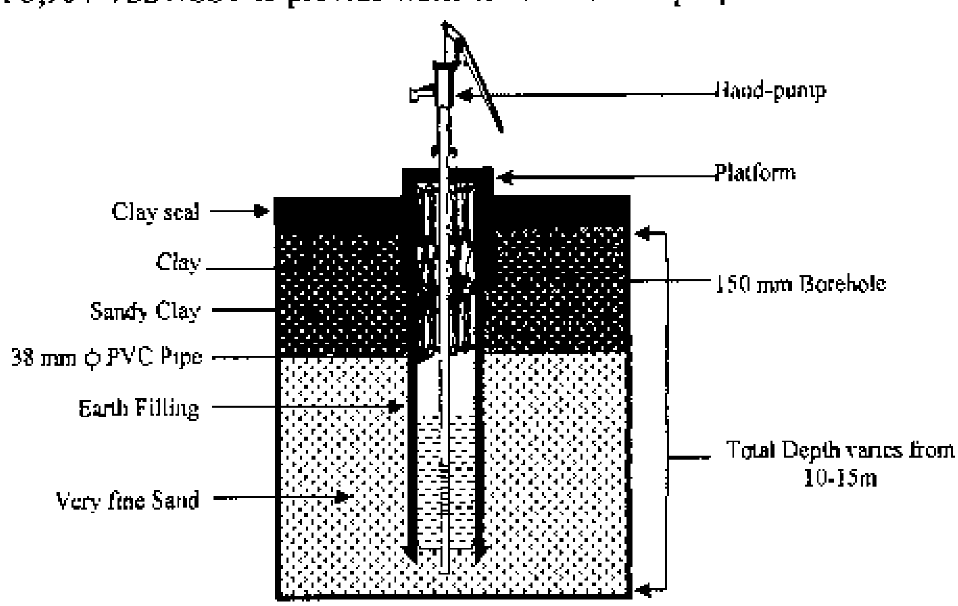


Figure 1 . Shallow and Very Shallow Shrouded Tubewell (VSST). (Source-Ahmed, M. F., 2003)

4.9.1.b. Deep Tubewell:

The deep aquifers, the part of groundwater in Bangladesh, have been found to be relatively free from arsenic contamination. In some places, the aquifers are separated by relatively impermeable strata. In Bangladesh two types of deep tubewells are constructed manually operated small diameter tubewell and large diameter power operated tubewells which are called Deep tubewells. The BGS and DPHE study has shown that only about 1% deep tubewell having depth greater than 150 m are contaminated with arsenic higher than 50μg/L and 5% tubewell have arsenic content above 10μg/L (BGS and DPHE, 2001). Sinking of deep tubewells in arsenic affected areas can provide safe drinking water. Some areas of the coastal region of Bangladesh are very suitable for construction of deep tubewell. Department of Public Health Engineering has sunk a total number of 81,384 deep tubewells mainly in the coastal area to provide safe water to 8.2 million people (DPHE, 2000).

4.9.1.c. Dug Well :

Dug well is the oldest method of groundwater withdrawal for water supplies. The water of the dug well has been found to be free from dissolved arsenic and iron even in locations where tubewells are contaminated (Ahmed, 2002). The following explanations may be attributed to the low arsenic content of dug well water:

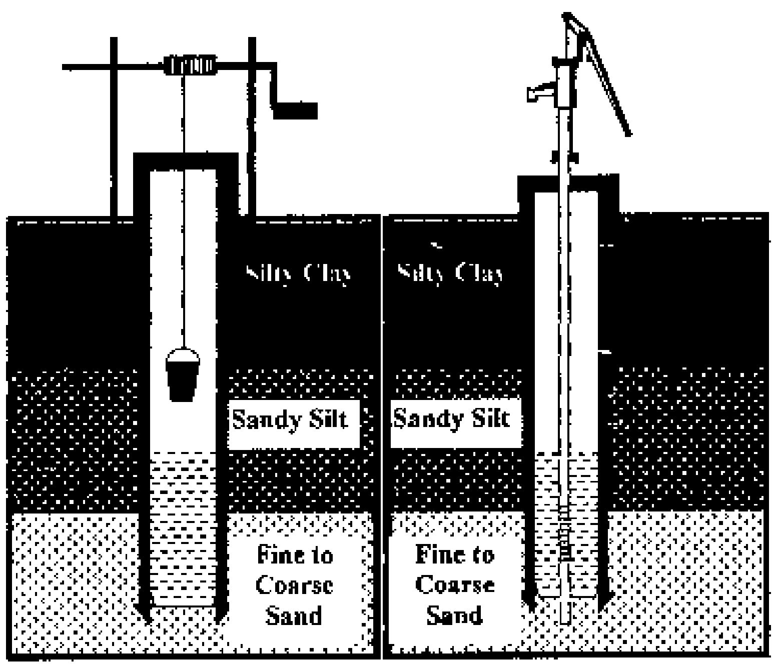
- The oxidation of dug well water due to its exposure to open air and agitation during water withdrawal can cause precipitation of dissolved arsenic and iron.
- Dug wells accumulates groundwater from top layer of a water table which is replenished each year by arsenic safe rain and surface waters by percolation;
- The presence of air and aerated water in well can oxidize the soils around dug wells and infiltration of water into wells through this oxidized soil can significantly reduce the concentration of arsenic in well water (Ahmed, F. M., 2002).

Dug wells are widely used in many countries of the world for domestic water supply. Usually no special equipment or skill is required for the construction of dug wells. For construction by manual digging, the wells should be at least 1.2 meters in diameter. Large diameter wells may be constructed for community water supplies. The depth of the well is dependent on the depth of the water table and its seasonal fluctuations Wells should be at least 1 m deeper than the lowest water table. A conventional dug well and a dug well with sanitary protection sunk in most common soil strata in Bangladesh are shown in **Figure-2**.

Dug wells are not successful in many areas of Bangladesh having thick impermeable surface layer. In areas with thick clay soil, dug wells do not produce enough water to meet the requirements. Again in areas having very low water table, there may be difficulty in construction as well as withdrawal of water.

Weaknesses of Dug Wells :

1. Risk of bacterial contamination is high if it is unprotected.
2. Collapse of well may be a problem of dug well.
3. Well may dry up or produce less water during dry session.
4. Dug well may not be a good option where water table is very low during dry session.
5. Dug well can only be constructed during dry session (Mid March to April)



(a) Conventional Dug Well **(b) Well with Sanitary Protection**

Figure-2 : Conventional and Sanitary Protected Dug Wells.

Source : Ahmed, M. F., 2003.

4.9.1.d. Infiltration Galley /Well:

Infiltration Galleys (IG) or wells can be constructed near perennial rivers or ponds to collect infiltrated surface water for all domestic purposes Since the water infiltrated through a layer or soil sand, it is significantly free from suspended impurities including micro-organisms usually present in surface water. Again, surface water being the main source of water in the galley/well, it is free from arsenic. If the soil is impermeable, well graded sand may be placed in between the galley and surface water source for rapid flow of water as shown in the (Figure-3).

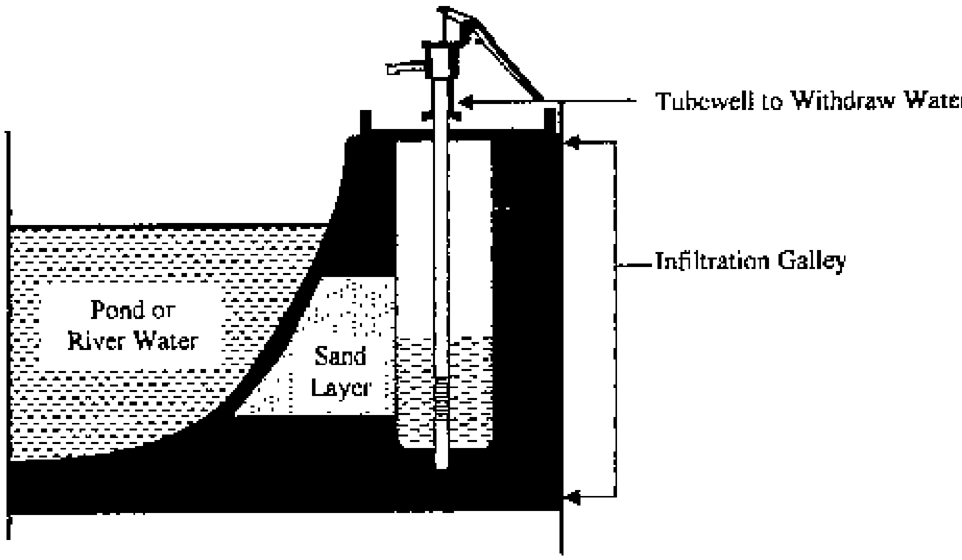


Figure-3 : An Infiltration Galley by the side of a surface water source.
Source : Ahmed, M. F., 2003

4.9.2. Surface Water :

4.9.2.a. Protected Ponds

A protected pond in a community can provide water for drinking purpose with minimal treatment and for other domestic uses without treatment. Traditionally, rural water supply, to a great extent, was based on protected ponds before and during early stage of installation of tubewell. There are about 1,288,222 ponds in Bangladesh having an area of 0.114 he per ponds and 21.5 ponds per mauza (BBS, 1997) About 17% of these ponds are derelict and probably dry up in the dry season. The biological quality of water of these ponds is extremely poor due to unhygienic sanitary practices and absence of any sanitary protection. In order to maintain good quality of water, a protected pond should not receive surface discharges or polluting substances and should only be replenished by rain and groundwater infiltration.

4.9.2.b. Pond Sand Filter

It is a prospective option for development of surface water. It is the construction of community type Slow Sand Filter (SSFs) commonly known as Pond Sand Filter (PSFs). It is package type Slow Sand Filter Unit developed to treat surface water. Slow Sand Filters are installed near or on the bank of a pond, which does not dry up in the dry season. The water from the pond is pumped by a manually operated hand tubewell to feed the filter bed, which is raised from the ground. The treated water is collected through tap(s). It has been tested and found that the treated water from a PSF is normally bacteriologically safe or within tolerable limits.

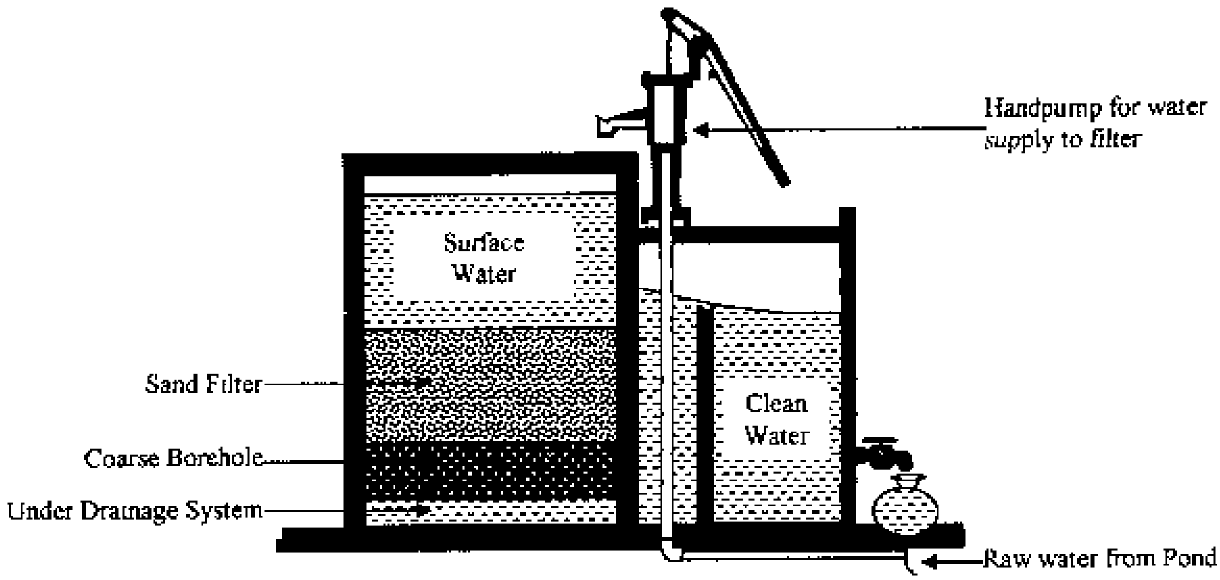


Figure-4 : Pond Sand Filter for Treatment of Surface Water.
Source : Ahmed, M. F., 2003.

The program initiated by DPBE with the construction of 20 experimental units in 1984 to utilize low saline pond water for water supply in the coastal area. It serves 200-500 people per unit. The PSF is being promoted as an option for water supply in arsenic affected areas. By June 2000, DPHE has installed 3,710 units of PSF. The PSF is a low cost technology with very high efficiency in turbidity and bacterial removal. It has received preference as an alternative water supply system for medium size settlements in arsenic affected areas. On average the operating period of a PSF between cleaning is usually two months, after which the sand in the bed needs to be cleaned and replaced The drawing of a typical PSF is shown in the **Figure-4**.

Selection of the Pond :

Pond should be selected based on the following criteria :

1. Pond should be cleaned and protected in all aspect;
2. Pond should not be used for fish culture;
3. Pond should not be linked with other water sources,
4. No latrine or no garbage pit within 30 m of the pond;
5. Pond will not be used for any type of washing (livestock or other domestic uses);
6. Pond will not be over flown during flood;
7. Pond should have enough water during dry season.

The major limitations of PSF are mentioned bellow:

1 It is difficult to find an appropriate/reserve pond for installation of PSF;
2. Operation and maintenance are difficult;
3. Not suitable for heavily contaminated ponds;
4. People complained of foul taste in pond water and may resort to use it for cooking only;
5. Conflicts with fish culture;
6. Many ponds dry up in the dry season in some parts of the country;

4.9.2.d. Household Filters:

Surface water containing impurities can be clarified by a pitcher filter unit or a small sand filter at the household level. It is an old method of water purification, once widely used in rural areas of Bangladesh. These processes of water treatment at household level have been phased out with the introduction of tubewells for village water supply. Pitcher filters are constructed by stacking a number pitcher (Kalshis), one above the other, containing different filter media as shown in the **Figure-5**. Raw water is poured in the top Kalshi and filtered water is collected from the bottom one. In this process, water is mainly clarified by the mechanical staining and absorption depending of the type of filter media used.

Small household filters can be constructed by stacking about 300-450 mm thick well graded sand on a 150-225 mm thick coarse aggregate in a cylindrical container as shown in **Figure-5** The container is filled with water and the filtered water is collected from the bottom.

The pitcher and other small household filters cannot completely remove micro-organisms if these are present in large numbers in raw water.

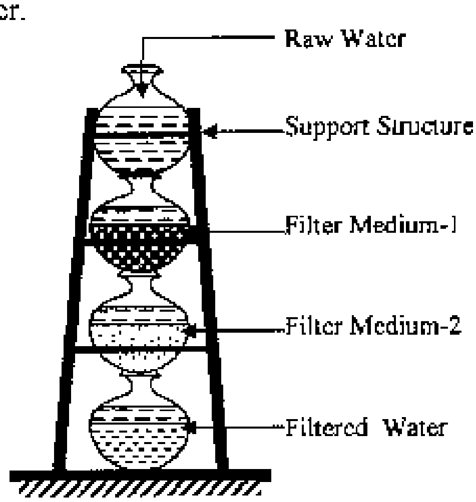


Figure-5: Pitcher (Kalshi) Filter :

Source : Ahmed, M. F., 2003.

The important characteristics of household filter are :

- Suitable for surface water treatment;
- Remove turbidity, color and micro-organisms,
- Complete removal of pathogenic micro-organisms is not guaranteed;
- Not suitable for high-turbid water;
- Difficulty in cleaning and keeping the system operational

4.9.2.e. Safi Filter :

Safi filter is a houschold filter in system developed by Professor Sayeed Safiullah of Jahangirnagor University, It works for filtering the arsenic contaminated water. One small unit fitter is designed to filter 40 liters of water per day. Design was done for the need of one family The filter comprises of two concrete buckets of different sizes, one of which placed inside the other. The upper bucket is filled with arsenic contaminated water which then flows through a permeable cover and is collected in the lower bucket where it is stored. The candle is prepared from a chemical mixture of laterite soil, ferric oxide, manganese di-oxide, aluminum hydroxide and mezoporous silica

Cost : DCH installed two types of Safi filter. One is small unit, which filtering capacity is 40L/24hrs and other is big, which filtering capacity is 120L/24hrs. Cost for the small unit is Tk. 900 and big unit cost Tk. 3,000 for 3 families

Weaknesses of Safi Filter:

1. Arsenic removal capacity is not satisfactory.
2. Flow rate is low, which can not meet the demand of a family
3. Not available in the local market.

4.9.2.f. DPHE-DANIDA Filter :

DANIDA with DPHE has developed arsenic removal home based filter. It is chemical treatment filter for removing arsenic. The technology of this filter is simple

Cost : DCH has installed 35 unit filter. Per unit cost is Tk. 3,50. One filter can use one family. Chemical cost per month Tk. 10.

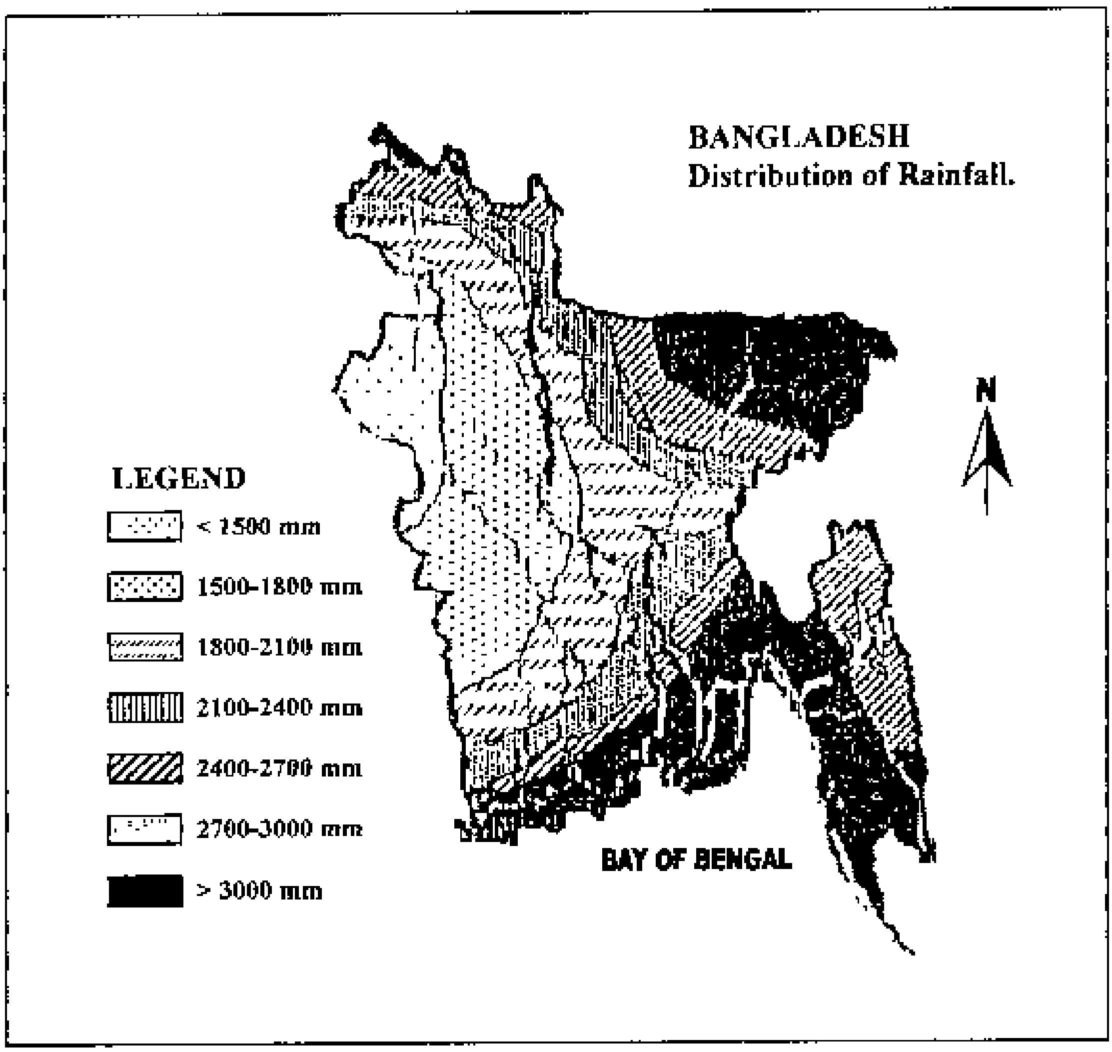
4. 9.3 Rain Water Harvesting

4.9.3.a. Rain water availability

Rainwater is an alternative source of water in Bangladesh Relatively higher rainfalls occur in the Eastern part of the country and highest rainfalls occur in North-Eastern region and Eastern part of the coastal area. The low rainfall, less than 1,500mm per year, occurs in the Western part of Bangladesh. In the coastal and hilly areas with greater intensity of fresh water source problem have higher rainfall, which is favourable for rainwater harvesting

A 12 year rainfall pattern based on the mean rainfall intensity recorded in 28 stations for the period from 1987 to 1998 is shown in Figure 9 (BBS, 1999). It appears that the average yearly rainfall in the country during 1987-96 varied from 1950 to 2900 mm In many countries in the world having half the rainfall of Bangladesh are practising rainwater harvesting for water supply.

Map : 10



Source : Rashid, H. Er., Geography of Bangladesh, Dhaka.

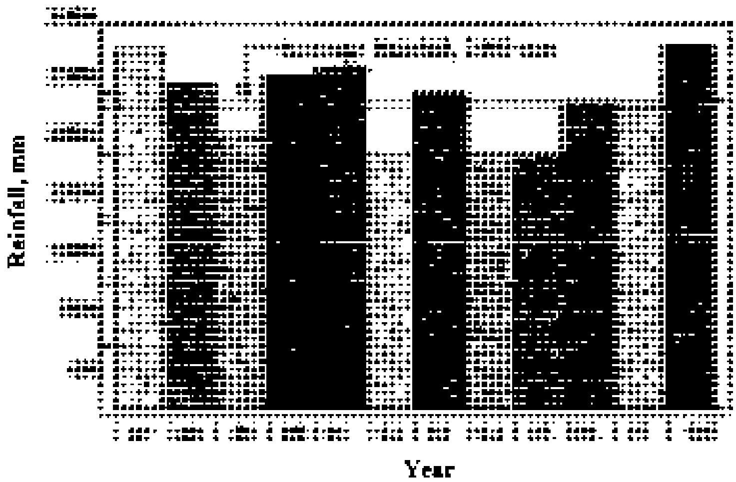


Figure-6 : Variations of Annual Rainfall in Bangladesh

Source : Ahmed, M. F., 2002.

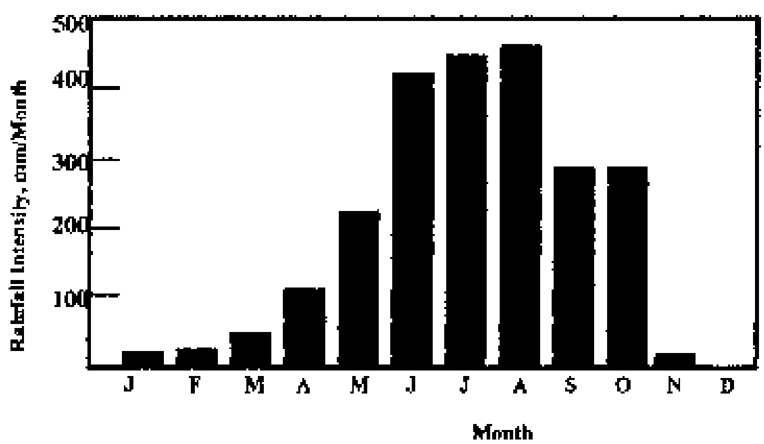


Figure-7: The Monthly Distribution of Rainfall in a Normal Year.

Source: Ahmed, M. F, 2002.

4.9.3.b. Rainwater Catchments and Rainwater Collection :

The catchment area for rainwater collection is usually the roof, which is connected with a gutter system to lead rainwater to storage tank. Rainwater can be collected from any types of roof but concrete tiles and metal roofs give cleanest water The C I sheet roofs commonly used in Bangladesh perform well as catchments areas. In Bangladesh 48% of the households have C.I. sheet, tiles and pucca roofs suitable for the collection of rainwater (BBS, 1997). Plastic pipes are set along the margin of the roof let to fall rainwater and to collect it in reservoirs. About 25% of the rainwater may be assumed to be lost by evaporation and for washing the catchments, area using first rain that produces inferior quality rainwater (Ahmed, M.F , 1999).

4.9.3.c. Quantity of Rainwater :

The average yearly rainfall in the country varies from 1900 to 2900 mm. However, there are some losses in the collection system and a part of the rainwater is used for washing of the catchments, area. The available rainwater can be estimated by the equation

$$Q = C\,I\,A$$

Where **Q** is the total quantity of rainwater available in m^3/year, and **A** is the catchments area in m^2 (Ahmed,M. F., 2002) Spatial variation of rainfall in Bangladesh is quite high. Lowest rainfall less than 1500 mm occurs in the western part of the country and the highest rainfall exceeding 4000 mm occurs in the north-east of Bangladesh. Therefore. the requirements of rainwater harvesting would vary from place to place depending on the total rainfall and its distribution over the whole year.

4.9.3.d. Storage Tank:

The unequal distribution of rainfall over the year requires storage of rainwater during rainy season for use in the dry season. The minimum volume of the storage tank **V**, required for rainwater can be computed by the equation (Ahmed, M F., 2002):

$$V = 0.365\,f\,q\,N$$

Where f is the fraction of water required to be stored for consumption of total available rainwater at a constant rate throughout the year. The total annual rainfall in 1996 as shown in **Figure-8** is approximately equal to the average annual rainfall of the last 12 years The rainwater availability mass curve assuming and cumulative consumption/demand of total available rainwater at constant rate is also shown in **Figure-8.**

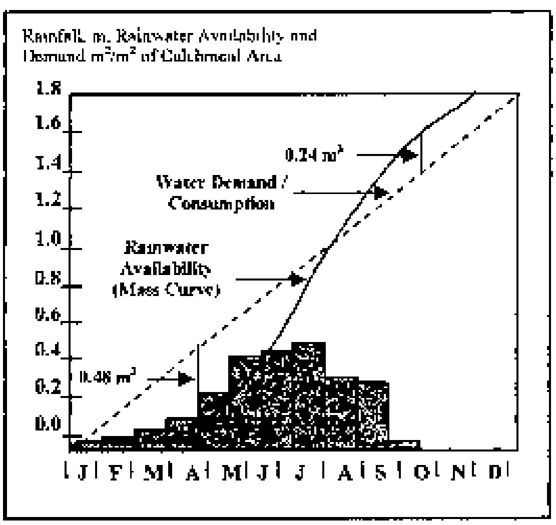


Figure 08 Rainfall Intensity, Cumulative Rainwater Availability and Demand.

Source : Ahmed, M. F, 2002

The mass curve has been prepared considering the fact that 75% of the rainwater would be available. It may be observed that there is a shortfall of 0.48 m^3 in the dry periods and an excess of 0.24 m^3 during rainy season. For full utilization of rainwater potential, a storage tank of capacity 0.72 m^3 that is 40% of the available rainwater is required for uninterrupted water supply at a constant rate throughout the year. However, if only drinking and cooking water is harvested, the sizes of the storage tank and catchment area would be smaller and within affordable range a family (Ahmed, M. F., 2002).

4.9.3.e. Quality of Rainwater :

The quality of rainwater is relatively good but it is not free from all impurities. Analysis of stored rainwater has shown some bacteriological contamination (Ahmed, M F., 2002). Cleanliness of roof and storage tank is critical in maintaining good quality of rainwater. The first run off from the roof should be discarded to prevent entry of impurities from the roof. If the storage tank is clean, the bacteria or parasites carried with the flowing rainwater will tend to die off. Some devices and good practices have been suggested to store or divert the first flow, cleaning of the roof and gutter at the beginning of the rainy season and their regular maintenance are very important to ensure better quality of rainwater. The storage tank requires cleaning and disinfecting at least once in a year.

4.9.3.f. Rainwater Harvesting: Advantages and Disadvantages :

Rainwater harvesting is being seriously considered as an alternative option for water supply in the arsenic affected areas in Bangladesh. The main advantages and disadvantages of a rainwater system are given below :

Advantages :

- The system is independent and suitable for scattered settlements.
- The quality of rainwater is comparatively good.
- Local materials and craftsmanship can be used in construction of rainwater system.
- Easy to maintain by the owner/user.
- The system can be located very close to the consumption points.

Disadvantage :

- The initial cost is high to setup the system
- Availability of water depends on the rainfall intensity and available roof area.
- The poor people may not have a roof suitable for rainwater harvesting.

- Mineral-free rainwater had a flat taste, which may not be liked by many.
- Mineral-free water may cause nutrition deficiencies in people who are on mineral deficient diets.

4.10 Strategic Plan for Arsenic Mitigation in Bangladesh :

A strategic mitigation plan is formulated and approached to the government of Bangladesh. The main elements of the plan are :

1. **Establishment of Standard Values for Arsenic in Groundwater :**

   Considering the widespread occurrences, scarcity of alternative safe water sources and technical capabilities in measurement and arsenic removal, the guideline values for Bangladesh may be recommended as follows :

Desirable Concentration	:	<0 01 mg/L
Maximum Allowable Concentration	:	0.05 mg/L.
Unsafe Water	:	> 0 05 mg/L.

2. **National Survey :**

   A nation-wide survey should be conducted to achieve the following goals.

   - Test of the quality of water of all tubewells
   - Delineation of the population exposed to arsenic contamination.
   - Identification of all arsenic affected people.
   - Preparation of the maps showing the hot spots in respect of contamination of groundwater.

3. **Provision of Safe Drinking Water :**

   The possible options for the provision of safe drinking water include :

   - Identification of safe and unsafe tubewells by marking green and red colour respectively.
   - Installation of tubewells in alternative aquifer producing water with low arsenic content.
   - Installation of community type treatment plants Protected ponds may provide safe water with minimal treatment.
   - Rainwater harvesting should be greatly encouraged as an alternative as well as supplementary water supply system.
   - Installation of community type arsenic removal plants attached or close to the tubewell to produce good quality water.
   - Development and installation of household level arsenic removal units are encouraged.

4. **Provision of Treatment and Medical Care :**

In order to relieve the arsenic affected people of the pains and agony, it is essential to :

- Provide medical and health care for seriously affected patients in health centres an hospitals.
- Organize symptomatic treatment such as skin care, providing vitamins and nutritious food etc.

5. **Awareness Building :**

People are to be made aware to :

- The possible health effects of drinking arsenic contaminated water as well as unsafe water from unprotected sources.
- Symptoms of arsenic contamination and possible places to seek help.
- Necessity of water test from a laboratory.
- Alternative sources of safe water good hygienic practices.

6. **Strengthening Water Quality Surveillance and Monitoring Capabilities:**

Regular examination of quality following national water quality survey is needed through strengthening of the local/regional water quality monitoring and surveillance capabilities.

7. **Building of Capacity though Training :**

Appropriate and comprehensive training programs are to be developed with the following targets :

- Development of skills of the doctors and health workers to diagnose cases of arsenic poisoning.
- Enhancement of the knowledge and skills of the engineers, hydro-geologist, NGO workers etc. to develop alternative safe water supply systems.

8. **Establishment of National Database and Information Centre:**

Establishment of a national database and information centre for arsenic contamination of drinking water and resulting arsenic toxicity through proper documentation is essential.

9. **Strengthening of Arsenic Measurement Capabilities:**

- Vehicle mounted mobile laboratories equipped with arsenic measurement facilities can help extending arsenic testing services closer to the communities.
- Development of reliable field test kits and standardization of procedure of tests are essential.

10. Establishment of Appropriate Research/Study programs :

The following research programs may be launched:

- Establishment of relation between arsenic ingestion and manifestation of symptoms of arsenic related diseases through extensive study in the affected.
- Assessment of clinical manifestations.
- Efficacy of drugs and other methods of treatment.
- Development of techniques of reliable arsenic detection, measurement and improvement.
- Identification of source of contamination, mode of propagation and hydro-geological conditions
- Alternative surface water based water supply options.
- Rainwater harvesting, storage and safe uses.

11. International, Inter-Disciplinary aod Inter-organizational Co-operation :

It requires :

- International collaboration and co-operation to exchange experience.
- Co-operation among the government organizations and ministries
- Collaboration and co-operation among professional groups.
- Close co-operation among government and non-government organization.

Source : Ahmed, M. F., 2000, Bangladesh Environment 2000, pp 165-170.

CHAPTER: 05

Geographical Description of the Study Area

CHAPTER: 05 GEOGRAPHICAL DESCRIPTION OF THE STUDY AREA

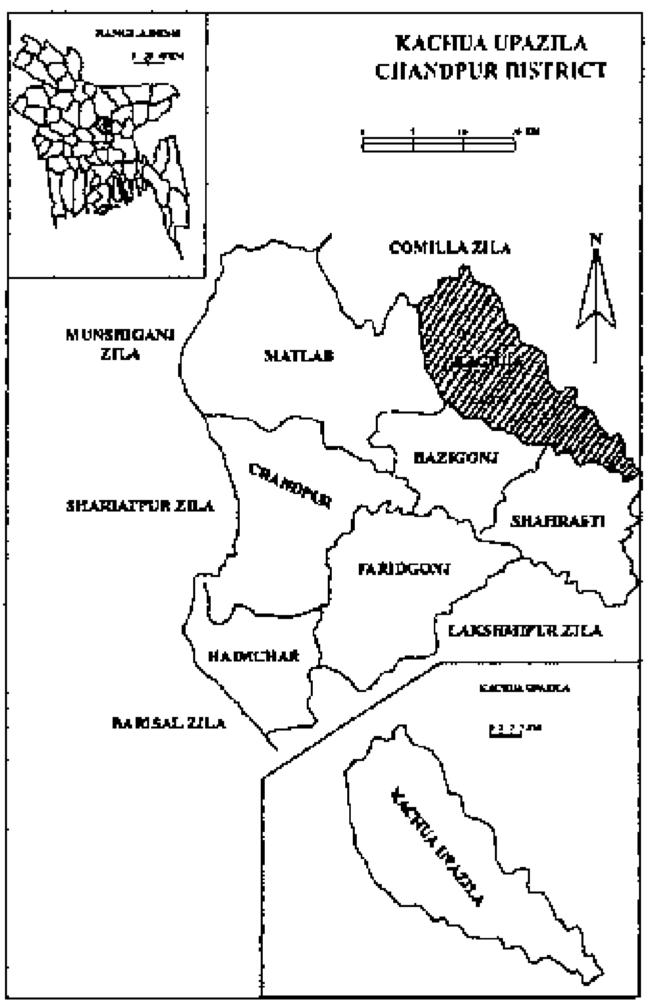
5.0 Introduction :

Geographical description of the study area, another literature of the thesis, has been taken from some books and journals to focus the various aspects of the study area such as location, boundary, area, population density, climate, communication, economic activities etc.

5.1 Case Study: Kachua

Kachua Thana is situated roughly with in $23^0 15'$ North latitude to $23^0 24'$ North latitude and between $90^0 44'$ East longitude to $91^0 01'$ East longitude under the district of Chandpur. It is located about 25 miles North-East corner of Chandpur town and about 80 miles South-East corner of Dhaka city on the way to Comilla. Kachua, the study area, is connected by a paved road with Chandpur and Dhaka-Chittagong road (**Map: 11**).

Map-11



Source : BBS, 1991, Bangladesh Population Census 1991, Zila-Chandpur

Kachua, the study area, is bounded by three Thanas of Comilla district namely Chandina, Barura and Daudkandi and by three Thanas of Chandpur district namely Matlab, Hajigonj and Sharasti. Elaborately, Kachua is surrounded on the North-East by Daudkandi, North West by Matlab, on the South and South-West by Hajigonj and Sharasti Thanas.

The population of Kachua Thana is 2,93,683 and out of this, the male and female population is 145956 and 147727 respectively. The male-female ratio is 100: 101 where as the national standard is 100 : 106 (Bangladesh Population Census 1999, Vol-2,). The total area of Kachua Thana is 235.61 sq. km. and the pepulation density is 1246 per sq. km On the other hand, the total households in the study area are 50262 and density of the household is 213 per sq. km. There are 12 Unions and 245 villages in Kachua Thana. The Unions are Ashrafpur, Bitara, Uttar Gohat, Dakshin Gohat, Uttar Kachua, Dakshin Kachua, Kadla, Karaia, Purba Pathair, Paschim Pathair, Purba Shahadevpur, Paschim Shahadevpur.

The climate of the study area, Kachua Thana, may be described as mild, equable and humid. Winter is cold and summer is hot here. The winter starts from November and ends till the end of February. The hot season is found from March to June The rainy season continues from mid June to September.

The mean winter (November to February) temperature is about 71^0 F. The summer season begins with strong North-West winds in the first week of March and continnes up to June. Generally June is the hottest (83.6^0F) month. The mean temperature (82.6^0 F) prevails from March to October. Temperature is generally uniform during the summer season.

Rainfall plays an important role to provide water in the ponds, soil and sub-soil. It also enriches the aquifers. The rain usually starts in April and continues up to October. But the rainfall is not uniformly distributed throughout the year. The dry season prevails from November to February. The average rainfall is only 2.78" in the dry season. Therefore, soil moisture deficiency is felt and irrigation is necessary. In this season, ponds become waterless, often hand-tubewells become inactive and scarcity of water prevails almost every where in Kachua. From the month March to May, when 17.43 inches of rainfall is received, the dry season prevails. As the result of the rainfall, the ditches and the ponds become the sources of water for bathing, washing and for other purposes in the study area.

The maximum rainfall occurs in the month of June, July and August, when the South-West monsoon wind from the Bay of Bengal containing heavy moisture passes over the region. The monsoon season lasts for five months from June to October. 53.65 inches rainfall occurs in this season which is 72.7 percent of the total rainfall for the year (Rashid,H.Er.,1991). Due to the heavy rainfall, water surplus is experienced during this season. People collect rainwater traditionally and use for different purposes like drinking, cooking, washing etc. Recently some advanced technologies are going to adopt to collect and storage rainwater at a large scale. Rainfall also occurs during sudden climatic depression which lasts for a few days. In this time, the low lands, ponds and ditches in Kachua become partially fulfill with water. The abundance of vegetation in Kachua in directly related to the physical and climatic condition. Heavy and well distributed rainfall in combination with sufficient heat and good soil is responsible for the greenery surface of the Kachua Thana. There are different varieties of fruit trees in Kachua Thana and the most common tress are mangoes, jack fruits, coconuts, guavas, bananas etc. Natural vegetation and cultivation in the region give the expression that the inhabitants make the most economic use of their precious land.

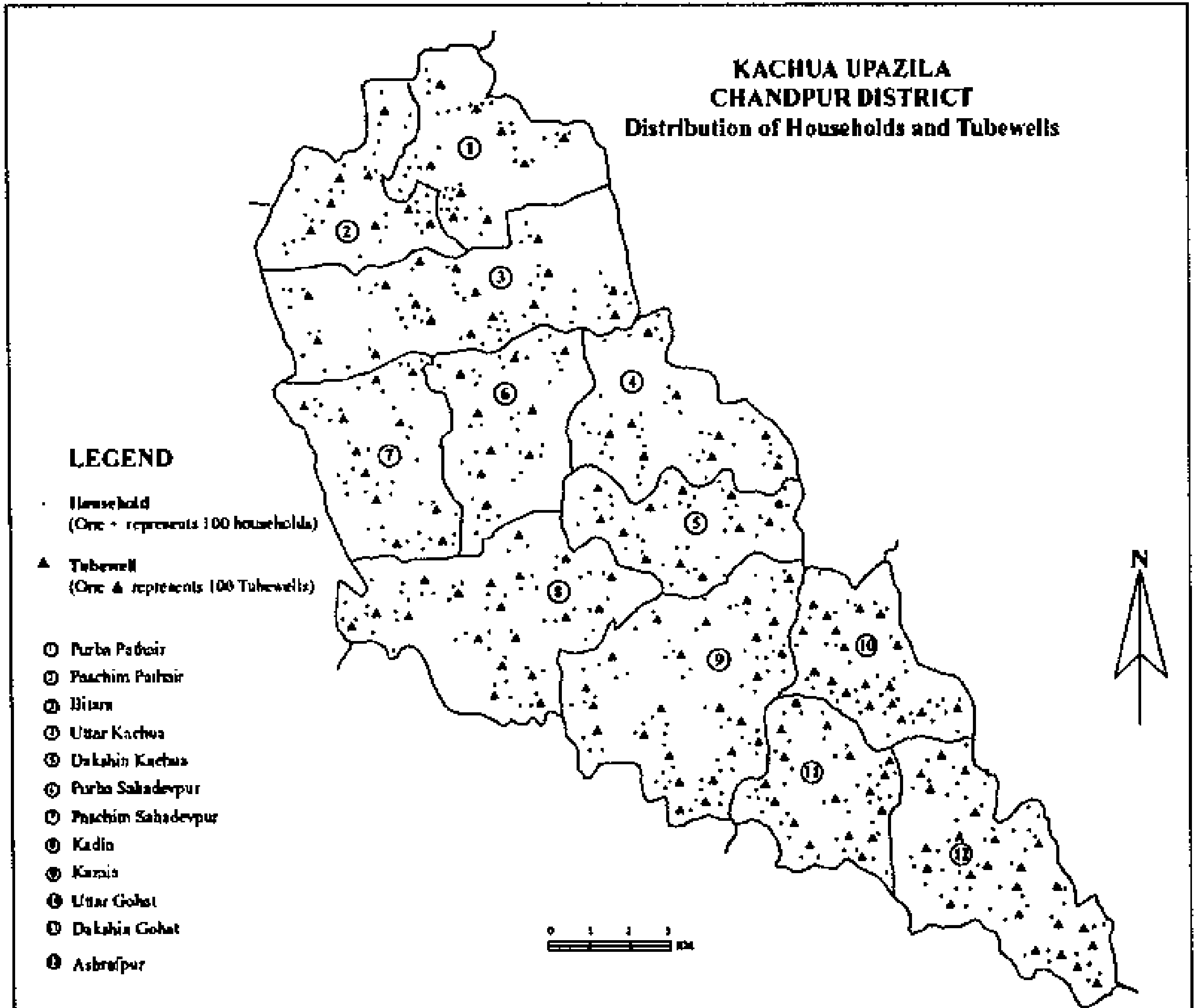
Kachua Thana, the study area, is connected by brick soling road with its surrounding Thana of both Comilla and Chandpur districts. Moreover, every corners of the Thana have easy access by motorized and non-motorized transports. The common means of transportation within the Thana are Bus, Baby Taxi, Tempo, Rickshaw and Bicycle. Although Kachua is a Thana, but its infra structure specially its road network is developed enough. Electricity is provided in each village of the Thana

The means of maintaining life of the inhabitants of Kachua Thana is primarily agriculture. Although rain and other climatic factors dictate the rhythm of agricultural operations, modern technology is followed to cultivate land and to other agricultural sectors. Cultivation of rice is the most important agricultural activity in Kachua. Potato, pulse, onion etc are also grown in this region.

Non-agricultural activities are expanding in the study area due to the rapid development of communication network. The NGO's are playing important role to enlighten the people to make them active and to reduce the environmental problem specially the problem of arsenic contamination in tubewell water.

5.1.1 : Union-wise number of population, households and tubewells in Kachua :

The total number of working tubewells in Kachua Thana is 17787 (GB, 2000) (Action Research on Community Based Arsenic Mitigation Project, July 1999 to August 2000). So it can be said that about 2.8 households in the study area depend on a single tubewell to obtain water **(Table- 12).**



Source : BBS, 1991, Bangladesh Population Census 1991, Zila-Chandpur.

There are 245 villages within 12 Unions in Kachua Thana of Chandpur district. So each Union has 1482.25 tubewells and each village has 72.6 tubewells on an average. Union-wise number of population, households and tubewells in the Kachua Thana of Chandpur district are given in the **Table-12.**

Table-12 : Union-wise number of population, households and tubewells in Kachua Thana of Chandpur District.

Unions	Total area in sq. km.	House hold	Population	Population density (Per sq. km.)	Total number of tubewells	No. of Tubewell in sq. km.	No. of household depend on a single Tubewell.	No. of people depend on a single Tubewell.
Ashrafpur	23.36	4942	27775	1189	2381	102	2.08	12
Bitara	29.61	5250	32646	1103	1594	54	3.29	20
Uttar Gohat.	14.60	3628	21305	1459	1835	126	1.98	12
Dakshin Gohat	14 48	3828	21134	1460	1727	119	2.22	12
Uttar Kachua	16 59	3616	20927	1261	911	55	3.97	23
Dakshin Kachua	13.54	3458	21024	155	1344	99	2.57	16
Kadla	26 97	5218	31487	1167	1916	71	2.72	16
Karaia	29 25	6463	38635	1321	2437	83	2.65	16
Purba Pathair	16.91	3613	20119	1190	878	51	4.11	23
Paschim Pathair	14.81	3140	18738	1265	754	51	4.14	25
Purba Shadevpur	16,92	3407	18593	1099	897	53	3 8	21
Pashchim Shadevpur	18.57	3699	21300	1147	1113	60	3 32	19
Total	**235.61**	**50262**	**293683**	**1246**	**17787**	**75**	**2.8**	**17**

Source: Field Survey, 2000.

Table-13 : Union-wise number of Households and Water Sources in Kachua Thana of Chandpur District.

Unions	Total number of House holds	Total number of Tubewells	Total number of Ponds	Total number of Rivers/Canals	Total number of Taps	Total number of Wells
Ashrafpur	4942	2381	329	-	6	18
Bitara	5250	1594	633	-	2	11
Uttar Gohat	3628	1835	105	-	3	20
Dakshin Gohat	3828	1727	42	-	-	5
Uttar Kachua	3616	911	500	15	-	11
Dakshin Kachua	3458	1344	967	-	3	13
Kadla	5218	1916	1722	1	12	6
Karaia	6463	2437	684	-	1	31
Purba Pathair	3613	878	660	8	-	2
Paschim Pathair	3140	754	418	62	-	3
Purba Shadevpur	3407	897	446	-	4	3
Pashchim Shadevpur	3699	1113	894	1	1	9
Total	**50262**	**17787**	**7400**	**87**	**32**	**132**

Source : BBS, 1991, Bangladesh Population Census 1991, Zila : Chandpur, pp 170-173.

5.1.2 : Union-wise number of Households and Water Sources in Kachua :

There are 7400 ponds in the Unions of Kachua Thana of Chandpur District and their distributional pattern is shown in the **Map-13**.

5.2 Alternative Safe Water Options in Kachua Thana of Chandpur District :

Different governmental and non-governmental organizations have launched their programs of strategic mitigation plan in the arsenic affected areas of Bangladesh for its remedy. In the Kachua Thana of Chandpur district, Grameen Bank and Department of Public Health Engineering (DPHE) are playing vital role through their massive programs in the study area including tubewell water test, marking the arsenic affected tubewells, finding arsenic affected patients, giving them treatment and providing safe water options etc.

Grameen Bank and DPHE have provided safe water options to the people of the study area. They have taken programs to treat groundwater in an acceptable level and to find out an easy and well acceptable way to treat arsenic contaminated tubewell water. The safe water options provided in the study area by the Grameen Bank and DPHE are discussed below.

Pond Sand Filter (PSF) :

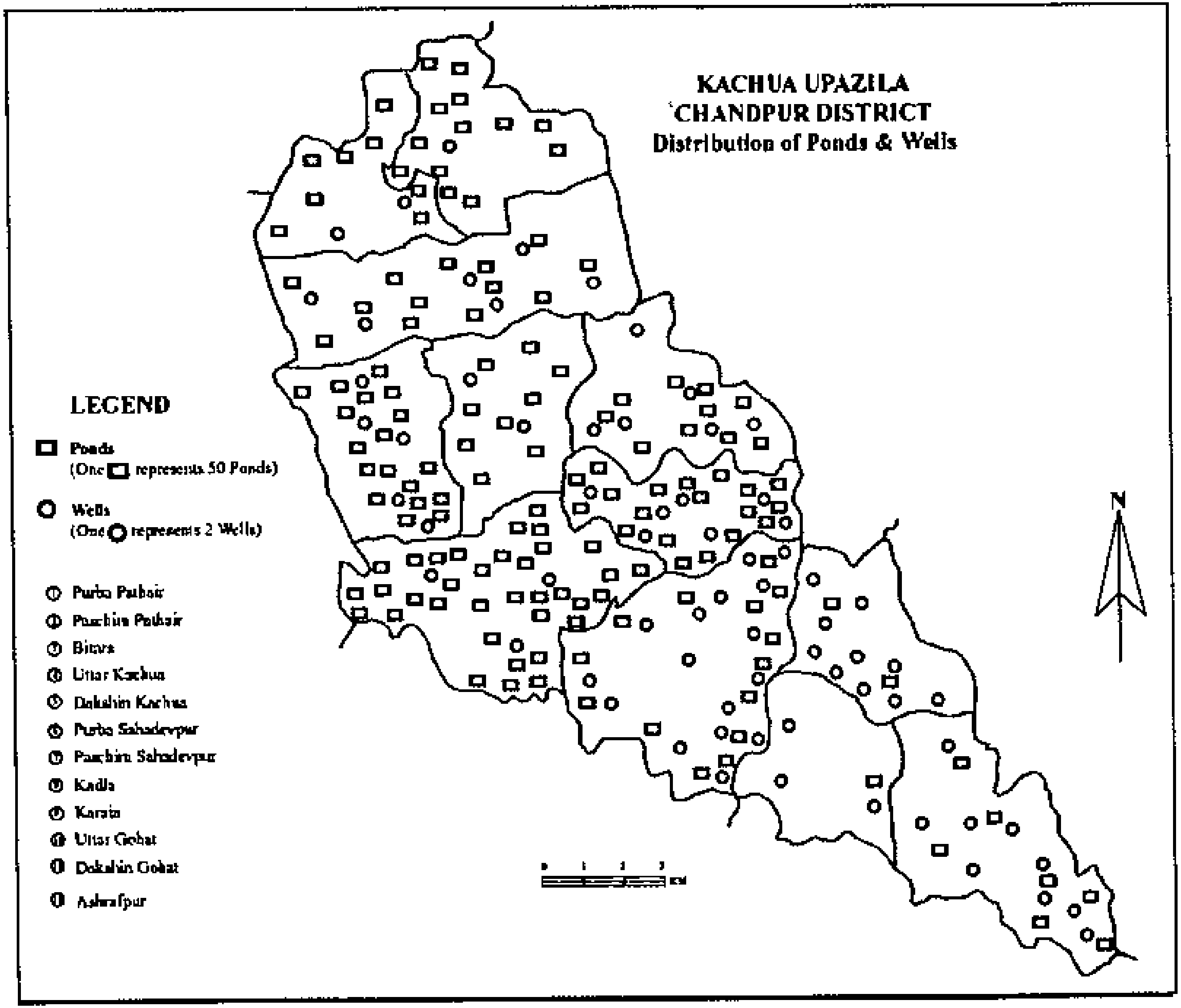
DPHE with funding from UNICEF has installed Pond Sand Filtration units in Kachua into which pond water is fed using a hand-pump. These units are called Pond Sand Filters (PSF). PSF technology is also considered appropriate for areas where ground water is contaminated with arsenic. Grameen Bank and DPHE have provided alternative safe water options. Photograph of Pond Sand Filter have given in the appendix (**Appendix-03**). In Kachua, there are a number of big ponds that contain sufficient water round the year. But hardly any of them fulfilled all the conditions needed to construct a PSF. So they constructed 10 PSFs beside 10 ponds in total **(Table-14)**.

Table-14 : Village-wise PSF list

Sl. No.	Union	Number of PSF
1.	Uttar Kachua	1
2.	Dakshin Kachua	1
3.	Koroya	1
4.	Sachar	1
5.	Dakshin Gohat	1
6.	Asrafpur	1
7.	Kadla	1
8.	Bitara	1
9.	Pathair	1
10.	Shadevpur	1

Source: GB, 2000, Report of Action Research on Community Based Arsenic Mitigation Project.

Map-13



Source : BBS, 1991, Bangladesh Population Census 1991, Zila-Chandpur.

Different Home-based Arsenic Removal Sand Filters:

Grameen Bank has installed three different types of home-based sand filter like Pitcher Filter, Chari Filter and Two-bucket Filters **(Table-16).** All these filters work on slow sand filtering system. This technology is proved very effective to remove arsenic. Water simply passed through different layers of brick- chips and sand in both Pitcher and Chari Filters. Grameen Bank has distributed more than 1500 sets of these filters. These are cheap, easily potable and can be maintained by individual persons or families. Pitcher Filter and its running state are also shown in the photograph **(in the appendix-03).**

Rain Water Harvesting (RWH):

Rainwater is safe for drinking if it is collected appropriately. Bangladesh receives abundant rainfall throughout the year, mean annual precipitation ranging from 1,400 mm (about 55 inches) along the country's east central border to more than 5,000 mm (200 inches) in the far North-East. A family of 6 in Bangladesh needs about 30 liters hygienically safe water everyday for drinking, cleaning and food preparation. A 20-day dry period requires approximately 100 liters of stored water. To mitigate the demand of water, Grameen Bank has constructed 162 rainwater harvesters in the study area for community use **(Table-15).** From May 2000 all of the 162 RWHs are working. The drawback of the technology is that rainwater is available only for a few months of the year. Fresh rainwater tastes good and is the safest for human body. But collection of rainwater in the proper way and preservation of this water for a long time are difficult for the poor at family level.

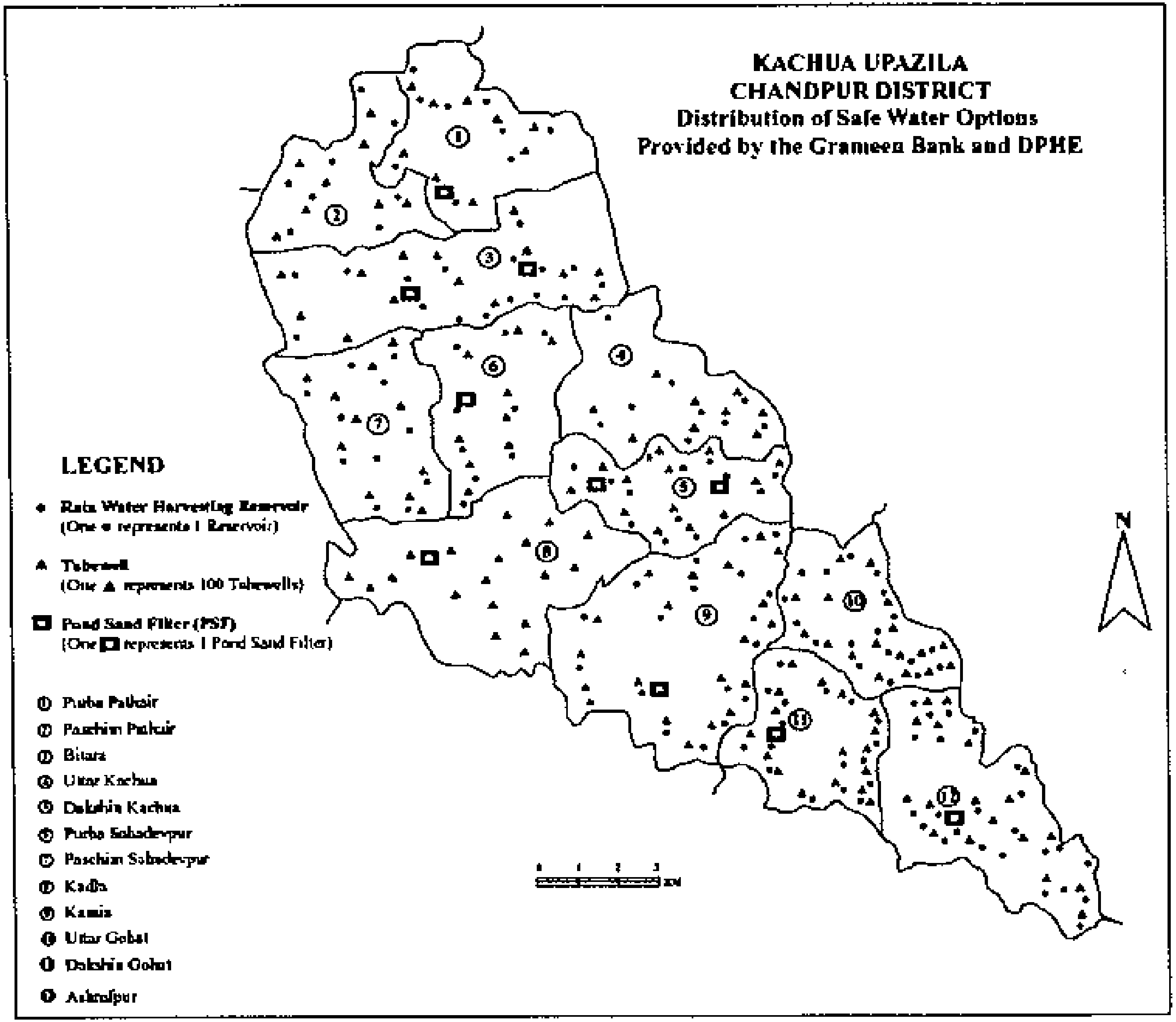
Table-15 : Number of Alternative Safe Water options constructed/supplied in Kachna Thana of Chandpur District.

Options	Kachua	
	Proposed	Constructed/Distributed
Pond Sand Filter (PSF)	9	10
Rain Water Harvester (RWH)	210	162
Safi Filter	210	30
Pitcher Filter	None	1500
Chari Filter	None	6
Two-bucket Filter	None	6

Source : GB, 2000, Report of Action Research on Community Based Arsenic Mitigation Project.

The distribution of tube wells, Pond Sand Filter (PSF) and Rainwater Harvesting Reservoirs are shown on the **Map- 14.**

Map-14



Source : BBS, 1991, Bangladesh Population Census 1991, Zila-Chandpur.

CHAPTER: 6

Analysis & Presentation of Data

CHAPTER: 6 ANALYSIS & PRESENTATION OF DATA RELATED TO THE STUDY OF ALTERNATIVE SOURCES OF SAFE DRINKING WATER FOR THE ARSENIC AFFECTED AREAS IN KACHUA THANA OF CHANDPUR DISTRICT.

6.0 Analysis of Data:

Every household was asked certain questions (according to the questionnaire) that provided certain profile, behavioral, psychological & socio-economic data like age structure, dependency ratio, sex, educational status, occupations, monthly income & expenditure, purpose of use of water from the existing sources, number of family dependent on a single tubewell, condition of getting water from the sources, availing tubewell water for drinking or any other purposes, present condition of tubewell water, peoples attitude about the use of arsenic affected tubewell water, way of concern about the presence of arsenic in tubewell water; arsenic affected condition of the family members, types of affection and sufferings, their treatment condition, treatment service providers, tubewell water testing, conditions of the water filtering instruments, condition of the existing alternative sources of safe drinking water and their relative distance from the houses of the households, providers of the safe drinking authority, required quality of safe drinking water per family, availability of water in the existing water sources, condition of the alternative water options like pond, pond sand filter, rainwater harvesting technique, purpose of use of water from alternative sources, roof material of the houses of the households and problems related to safe drinking water in the arsenic affected area of Kachua Thana of Chandpur district. The **Table-16** gives the view of the factors at a glance those help to fulfill the objectives of the study:

Table-16 : Factors Discussed in the Analysis Chapter.

Objectives	Factors
1. To study the extent and nature of arsenic contamination in the drinking water in the study area.	Condition of existing water sources and their distribution, purpose of use tubewell water, number of family dependent on a single tubewell, availability of water from the tubewell and present condition of tubewell water
2. To identify and evaluate the initiatives taken by the government and non-government organizations to mitigate the arsenic contamination in drinking water	Testing of water of the tubewells, marking the tubewells in red and green colour to show arsenic affected or not affected and conditions of arsenic contaminated water purifying techniques
3. To find out the alternative sources of safe drinking water for the arsenic affected people of the study area.	Alternative water options, provider of these options, conditions of these options, relative distance of these options.
4. To assess community awareness and perception.	People's affinity to use contaminated water of the tubewell, aware to the people not to use contaminated water.
5 Suggest some policy guidelines to integrate the alternative sources to existing sources to mitigate the severity of arsenic problem of rural people in Bangladesh.	After finding information and facts about the problem and reviewing the existing guidelines, final policy will be suggested.

6.1 Information about Socio-economic condition of the Respondents in the Study Area:

6.1.1 Age Structure :

According to the field survey, if has been found that 41.76 percent family members of the households are in 0-19 years age group that is lower than the national age structure. By the forecasting of BBS Census in 1991, about 54 percent of the total population is that age group. It has also been found that 18.57 percent family members of the Kachua Thana are in 20-29 age group which is generally known as young and workable group. Moreover it is found that 14.65 percent and 10.55 percent of the family members of the households are in the (30-39) and (40-49) age groups successively. These two groups comprise together 25.20 percent which is generally known as mature group in the demography. Generally (20-29), (30-39) and (40-49) age groups are the income generating groups and they take vital role in the national economy. On the other hand, economically they are independent in the family and they have to mitigate all the needs of the family. In Kachua, it has been found through the field survey that 43.77% family members of the households lie in these groups. Only 6.97 percent and 7.50 percent family members of the households are in (50-59) and 60 and above age groups and they make together 14.47 percent. These groups are also known as dependable population in the upper age group **(Table-17)**.

Table 17 : Age Structure of the Family Members of the Households.

Age Structure	Frequency	Percentage
0-19	479	41.76
20-29	213	18.57
30-39	168	14.65
40-49	121	10.55
50-59	80	6.97
60 and above	86	7.50
Total	**1147**	**100**

Source: Field Survey, 2000

6.1.2 Dependency Ratio :

$$\text{Dependency Ratio} = \frac{P_{0-15} + P_{50+}}{P_{16-50}} \times 100$$

Here P_{0-15} = Population within the ages (0- 15) years.
P_{50+} = Population above 50 years
P_{16-50} = Population within the ages of (16-50) years.

$$\text{Here Dependency Ratio} = \frac{503}{644} \times 100$$

= 78.11
= 78 (approximately)

From the findings of the survey, it is revealed that there are less dependable people (43.85%) than undependable people (56.15%) in Kachua Thana (**Table-18**).

Moreover, the dependency ratio is 78 which indirectly reflect the people's sound economic situation.

Table-18 : Dependency Ratio of the Family Members of the Households.

Types	Frequency	Percentage
Dependable	503	43.85
Undependable People	644	56.15
Total	**168**	**14.65**

Source: Field Survey, 2000.

6.1.3 Sex Composition :

From field survey, it has found that about 57.80 percent of the family members of the households are male and about 44.20 percent is female in category. So the sex ratio (Male : Female) of the total family member of the households is 136:100 which is higher than the national sex Ratio (106:100) for rural areas is Bangladesh (BBS, 1994) (**Table-3 in the Appendix**).

6.1.4 Educational Status :

It has been found through the field survey that about 15 26 percent of the total family members of the households are illiterate, where as 38.01 percent of the people possess primary level of education. According to the findings, it is revealed that 84 74 percent family members of the households are literate in different levels. 4.62 percent family members of the households possess graduate degree or above level of education. From this information it can be said that the study area is a zone of educated people.

6.1.5 Occupation :

It has been found from the survey that majority of the young and working people of the study area are farmer (20.49 percent). So it can be said that the dominating economic activity of the people is primary in nature i.e. cultivation. This is for the soil is so fertile which lies in the flood plain region, a major categories of physiographic divisions of Bangladesh. But a notable proportion of the family members of the households are engaged in the tertiary economic activity i.e. in business (6.89 percent), service both in private and government (6.71 percent) sectors, household worker (1.31 %) and day labourer (1.39%). Probably the proximity of the capital city (two and half an hour distance by bus from Kachua to Dhaka) acts as the reason for diversity of economic activities like business and service both in private and government sectors

It has also been found from the survey that most of the female members of the households are house wives (18.31 percent of the total surveyed population). The study shows that about 31.21 percent of the family members of the households are students (**Table-19**). This information is effective to comprise the high level literacy in Kachua Thana. About 7 67 percent family members of the households live on different activities like mason, porter etc. 5.23 percent of the total family members of the households have secondary occupation. The major activity of them is cultivation (60 percent of the secondary occupation) The next major secondary occupation of the family members of the household is business (20 percent). A notable proportion (10 percent) of the family members of the households is day labourer as their secondary occupation.

Table -19: Occupation of the Family Members of the Households.

Type of Occupation	Primary Occupation		Secondary Occupation	
	Freq.	%	Freq.	%
Farmer	235	20.49	36	60
Household Worker	15	1.31	-	-
Day Labourer	16	1.39	6	10
House Wife	210	18.31	1	1.67
Unemployed	58	5 06	-	-
Service Holder (Private)	47	4.09	1	1.67
Service Holder (Govt.)	30	2.62	-	-
Business man	79	6.89	12	20
Rickshaw/Van Puller	11	.96	-	-
Student	358	31.21	-	-
Others	88	7.67	4	6.66
Total	**1147**	**100**	**60**	**100**

Source · Field Survey, 2000

6.1.6 Occupation of the Household Head :

It is evident from the survey that majority of the household heads in Kachua are farmer (41 percent) as their principal occupation. Moreover, 25.50 percent of the household heads are engaged in business for their livelihood. On the other hand, 18.50 percent of the household heads are service holder whether in the private or government offices. It is also evident that 17% of the total household heads in the surveyed area have the secondary occupation. Among them most of the heads (76.47%) are involved directly or indirectly with agricultural activities. Rest of the heads major secondary occupation is business (11.76 percent) and a few proportions of them are day labourer (5.88 percent).

6.1.7 Income per Month :

It has been found from the survey that major family's income is more than Tk. 5,000/- per month. So it can be said that the maximum families of the study area are in the middle class.

Table- 20. Income of the Household per Month (Tk.).

income Group (Tk.)	Frequency	Percentage
0 - 1000	2	1
1001 - 2000	12	6
2001 - 3000	24	12
3001 - 4000	30	15
4001 - 5000	35	17.50
5000^+	97	48.50
Total	**200**	**100**

Source: Field Survey, 2000.

6.1.8 Expenditure per Month :

From the field survey, it has been found that maximum families of the households (32.50%) expense more than Tk. 5,000/- per month. Moreover, 23 percent of the families expense Tk. 4,001/- to 5,000/- per month. So it can be said that 55.50 percent family's expenditure is more than Tk. 4,001/- per month. It is evident that in the class group of Tk $4,000^+$, the percentage of family of the households is higher (66%) in case of monthly income than that of monthly expenditure i.e. (55.50%) From this information it can be said that the middle class people (the maximum people according to the findings) of Kachua Thana expense less money than their income, i.e. they have tendency to save money. It is also same for the lower income group especially Tk. (0/-2,000/) group. On the other hand, the reversed situatioo is found for the income group of Tk. 2,001/- 3,000/. In this group, the percentage of family of the households is higher in case of monthly expenditure than that of monthly income **(Table-6 in the Appendix).** So it can be said that economic deficiency condition prevails among that income group of families in the study area. Actually, this data is converted to moothly basis from annual.

6.1.9 Monthly Family Expenditures :

From the field survey it has been found that maximum 31 percent of the total households spend Tk. 2,001/- to 3,000/- per month for their food. About 24 percent of the households spend Tk. 1,001/- to 2,000/- per month for food expenditure. These two groups of percentages are quite higher than 9.52 percent households of food expenditure group of Tk. 4,001/- to 5,000/-. On the other hand, 14 percent of the households spend the least amount of money for food per month (maximum Tk 1,000/-) and this percentage is higher than 9.50 percent and 10.00 percent households of food expenditure groups of Tk. 4,001/- to 5,000/- and Tk. $5,000^+$/- respectively.

Through field survey it has tried to know the economic capability or general tendency of the people in the study area to spend money for their two basic needs, i.e. for food and for clothing. The findings also show that maximum people (70.50 percent of the households) spend not more than Tk. 1,000/- for their clothing in a month. Moreover, there are the least percentage of people (2.5 percent) spend Tk 3,000/- and above per month for their clothing. So it can be said that expenditure for clothing is quite low in the study area. There is a general practice to buy cloths one or two times in a year.

6.2 General Information about Water Sources in the Study Area:

6.2.1 Quantity of Drinking Water needed per Family per day:

What quantity of drinking water is needed per family per day is an interest of the study. Through survey it is found that 22% families needed 21-40 litters, 19% families needed 21-40 liters and also 19% within 20 litters of drinking water in every day. It is also revealed that about 60% families needed up to 40 litters of drinking water per day.

6.2.2 Purpose of Use of Water :

From the survey, it is evident that ponds are the most depending sources (54.50%) and tubewells are the second prior sources of water (41.71%) in the study area. These two sources comprise 96.2 1 % of the total sources from where people collect water for different purposes. It is also found that people in the study area mainly drink tubewell water (77.5% of the total drinking water sources). Pond water (26% of the total drinking water sources) is the second option for the same purpose (**Table-21**).

Table-21. Purpose of use of Water from different Sources in the Study Area.

Purposes	Tubewell		Deep Tubewell		Pond		River/Canal		Rainwater Harvesting		Pond Sand Filter	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq	%
Drinking	155	38.65	7	53.85	31	6 77	3	27.27	3	60	1	33.33
Cooking	152	37 90	6	46.15	38	8.29	2	18.18	1	20	1	33.33
Bathing	24	5.98	-	-	172	37 55	4	36.36	-	-	-	-
Cleaning/washing	57	14.21	-	-	139	30.35	2	18.18	1	20	1	33.33
For all purposes	13	3.24	-	-	78	17.03	-	-	-	-	-	-
Total	401	100	13	100	458	100	11	100	5	100	3	100
Total No. of Sources	401		13		458		11		5		3 = 891	
Percentage	**45**		**1.46**		**51.40**		**1.23**		**.56**		**, .33 = 100**	

Source: Field Survey, 2000.

In case of cooking, it is found that people mainly use tubewell water (76% of the total cooking water sources). Pond water is also used (19% of the total cooking water sources) for the same purpose in the study area. For bathing, they usually use pond water (86% of the total bathing water sources) and a few proportion of them use tubewell water (12% of the total bathing water sources) for the same purpose. It is also found that people get water for drinking and cooking purposes from Rainwater Harvesting Reservoirs and from Pond Sand Filtering (PSF) at a very lower rate (2% for drinking and cooking purpose from Rainwater Harvesting Reservoirs and 1% from PSF for the same purpose).

6.2.3 Getting Sufficient Supply of Water from Tubewell :

From the survey, it is evident that majority of the people (about 82% of the total households) in the study area are getting sufficient water from the existing tubewells and only 18 percent people are not getting water as they need. So it can be said that the people of the study area are not facing trouble with the quantity of water from the existing tubewells for their drinking, cooking and other purposes (**Table-22**).

Table-22. Information about Getting Sufficient Supply of Water from Tubewell.

Condition of Getting Water	Frequency	Percentage
Get sufficient Water	164	82
Do not get sufficient water	36	18
Total	**200**	**100**

Source: Field Survey, 2000

6.2.4 Availing of Water from Different Sources due to Insufficient Condition of Water Supply from the Existing Tubewells :

It is found from the survey that a few percent of people (about 18 percent of the total households) are not getting sufficient water from the existing tubewells in the study area. These suffering people avail water from different sources, when insufficient water supply condition from the existing tubewells prevails. It is found from the survey that these suffering people collect water mainly from the nearest ponds (91.18%) and rivers or canals (2.94%) in the study area (**Table-23**).

Table-23. Information about Availing of Water from Different Sources due to Insufficient Condition of Water Supply from the Existing Tubewells.

Sources of Water Supply	Frequency	Percentage
Pond	31	91.18
River / Canal	1	2.94
Other Tubewell	0	0
Deep Tubewell	0	0
Others	2	5.88
Total	34	100

Source: Field Survey, 2000.

6.2.5 Number of Family Dependent on Single Tubewell :

The important attempt of the survey through questionnaire was to know how many people are depended on a single tubewell in the study area. It is found that 1-2 families, depended on a single tubewell for water, are the majority of families (about 26.5 percent of the total surveyed families); 34 families, depended on a single tubewell, are the second highest category of the families (about 23%) and 1-4 families depended on a tubewell, are about half of the total families (about 49.5%). There are a remarkable number of families (11 or about 19.5%) who are depended for water on a tubewell in the study area. So it can be said that there is no homogeneity in distribution of tubewells in the study area (**Table-24**).

Table-24. Information about the Number of Family Dependent on Single Tubewell.

No. of Family	Frequency	Percentage
1-2	53	26.5
34	46	23
5-6	35	17.5
7-8	14	7
9-10	13	6.5
11 and above	39	19 5
Total	200	100

Source: Field Survey, 2000

6.2.6 Condition of Getting Sufficient Water from the Sources throughout the Year :

From physiographic context, the study area lies in the category of flood plain region created by sedimentation in the contemporary Holocene period. On the other hand, adequate rainfall occurs in this region in the rainy season due to the effect of South West monsoon wind blowing from the Bay of Bengal.

Table-25. Information about the Condition of Getting Sufficient Water from the Sources Throughout the Year.

Conditions of getting sufficient water from the sources	Frequency	Percentage
Get sufficient water at all seasons	172	86
Get sufficient water only at wet seasons	12	6
Do not get water all the seasons	16	8
Total	**200**	**100**

Source : Field Survey, 2000.

For the above circumstances, there is enough water in the rivers and ponds of the territory as well as in the aquifers i.e. the underground water storages. It is also evident from the survey that most of the people of the study area (about 86% of the total households) get sufficient water from the existing sources throughout the year. Only 6% people get sufficient water in the wet season and a notable proportion of the people (8% of the total households) do not get sufficient water from the existing sources at all the seasons.

6.2.7 Alternative Sources of Water in case of Getting Insufficient Water at all the Seasons from the Existing Sources :

According to the survey information, about 8% people of the study area do not get sufficient water from their existing sources throughout the year. Moreover, 6% people avail water only in the wet season from their existing sources. It is also evident that most of these suffering people (80% of the households) are to depend on the ponds within their proximity. A few proportion of that people (1%) are to pitch water for drinking, cooking and other purposes from the red marked i.e. from the contaminated tubewells.

6.3 Information about Tubewell Water :

6.3.1 Availing Tubewell Water for drinking or any other purposes :

It is known from the survey that about 90% people of the study area are depended on tubewell water for drinking or any other purposes. 10% people avail water for different purposes from different sources in spite of contaminated tubewells.

Table-26. Information about Availing Tubewell Water for drinking or any other purposes.

Availing Tubewell water	Frequency	Percentage
Avail	180	90
Do not avail	20	10
Total	**200**	**100**

Source: Field Survey, 2000.

6.3.2 Present Condition of Tubewell Water :

Through the survey, it is found that all most all tubewells (98.5% in the study area are arsenic affected **(Table-27).** But it is also found that most of these contaminated tubewells (91 %) are using frequently (**Table-9 in the appendix**) for different purposes.

Table-27. Information about the Present Condition of Tubewell Water.

Present condition of the Tubewell water	Frequency	Percentage
Arsenic affected	197	98.5
Not Arsenic affected	3	1.5
Total	**200**	**100**

Source: Field Survey, 2000.

6.3.3 Time of Detection of Arsenic in the Tubewell Water first.

When the people could know the presence of arsenic in tubewell water nearby of the households house an attempt of study was conducted in the month of April 2000. It is found that about 31 % people in three months ago, 14% people in four months ago and maximum people (60.5%)

within the last four months could know the presence of arsenic in tubewell water nearby the households house in the study area. But all the people (100%) could come to know the presence of this toxic element in the tubewell water of the study area within the last six months.

6.3.4 How the People came to know the presence of Arsenic in Tubewell Water first :

Almost all people (about 100 percent) of the study area are concerned about the presence of arsenic in tubewell water. Most of them could know it first from the NGO's water test and some of the people from GO's water test in the territory. A man could know the presence of arsenic in tubewell water by his self initiative i.e. he tested tubewell water by himself.

6.3.5 The Testing Anthority of Tubewell Water :

From the field survey it is known that both the governmental organizations (16%) and the nongovernmental organization (83.5%) have tested tubewell water in the study area to detect arsenic in water. Maximum water tests were conducted within three months before (50.5%) and above three months before (49.5%) from the time of survey (April, 2000). After water test maximum tubewells (99%) are marked with red (means arsenic contaminated) and green (means not arsenic contaminated) color **(Table-29).**

Table-28. Information about the Testing Authority of Tubewell Water.

Water testing authority	Freq.	%	Water tested before the time of survey							
			1 month		2 months		3 months		Above 3 months	
			Freq.	%	Freq.	%	Freq.	%	Freq.	%
GO	32	16.00	2	1.00	8	4.00	10	5.00	12	6.00
NGO	167	83.50	30	1.50	26	13.00	52	26.00	86	43.00
Self	1	.50							1	.50
Total	200	100	5	2.5	34	17	62	31	99	49.5

Source: Field Survey, 2000

The survey finding also shows that 99% of the red marked tubewells are used by the people frequently **(Table-29).** It is known from the previous tables **(Table-27 & 29)** that water of maximum tubewells (99%) are arsenic affected and most of them (91%) are using for cooking and drinking purposes. So a little difference is found in context of use of arsenic contaminated tubewell in the study area.

Table-29. Information about the Marking and Using Condition of the Arsenic Affected Tubewell.

Water testing authority	Freq.	%	Using condition of the red marked tubewell			
			Using		Not Using	
			Freq.	%	Freq.	%
Marked	198	99.00	194	98.92	14	100
Not Marked	2	1.00	2	1.07		
Total	200	100	186		14	

Source: Field Survey, 2000.

6.3.6 Purpose of Use of Water Availing from Arsenic Affected Tubewells :

From the survey it is found that 9 1 % of the arsenic contaminated tubewells are on use (**Table-9 in the appendix**). Water collected from these tubewells are generally using for drinking (34.85%), cooking (26.01%), bathing (16.67%) and washing (21.72%) purposes. It is also revealed that arsenic contaminated water from tubewells are mainly using for drinking and cooking (60.86%) purposes in the study area **(Table-30).**

Table -30. Information about the Purpose of Use of Water Availing from Arsenic Affected Tubewells.

Purpose of use water from arsenic affected Tubewells	Frequency	Percentage
Drinking	138	34.85
Cooking	103	26.01
Bathing	66	16.67
Washing clothes	86	21.72
Others	3	.5
Total	**396**	**100**

Source: Field Survey, 2000

6.3.7 The Advising Authority not to Drink Contaminated Water :

From the field survey it has been revealed that most of the people of the study area are informed about the presence of arsenic in tubewell water, adverse effect of arsenic in human body and are also conscious not to drink arsenic contaminated water. But how they have come to know the presence of arsenic in tubewell water within this proximity and who has informed them about this hazard are one of the quos of the study. From the survey it is known that most of the people (74% of the total households) are informed by the NGO's aod a notable proportion of the people of the study area (23% of the total households) are advised by the GOs about the negative health consequences of arsenic. A very few number of people (3% of the households) has given their view that they have come to know about this climax from the situation by themselves in spite of the GOs or NGOs.

6.3.8 Condition of Availing Arsenic Free Water :

From the survey it is evident that most of the people of the study area (about 83% of the total households) do not get arsenic free water. It is found that people in the affected area are provided arsenic free water mainly by the GO's (about 57% households opinioned) and in some cases by the NGO's (about 3 1 % households opinioned). People also get arsenic free water by self ioitiatives (about 3% households opinioned) **(Table-31).**

Table-31. Information about the Condition of Availing Arsenic Free Water.

Condition of availing Arsenic free water	Freq.	%	Provider of arsenic free water					
			GO		NGO		Self	
			Freq.	%	Freq.	%	Freq.	%
Avail	35	17.50	20	57.14	11	31 43	4	11 43
Do not avail	165	82 50						
Total	200	100						

Source: Field Survey, 2000

6.3.9 Condition of Water Filtering Instrument :

Although various studies and information showed that a severe arsenic disaster in drinking water in the study area prevails but no remarkable actions put forward for its immediate remedy. It is opinioned that water filtering is the most prominent and adoptable technique to remove arsenic from water in context of socio-economic condition of the people of Bangladesh. Through the survey it is found that most of the people in the study area (about 86% households) do not have any water filtering instruments

Table-32. Information about the Condition of Water Filtering Instrument.

Condition of water filtering instrument	Freq.	%	Filtering instrument provided by					
			GO		NGO		Self	
			Freq.	%	Freq.	%	Freq.	%
Have	28	14	3	10 71	23	82.14	2	7.14
Have not	172	86						
Total	200	100						

Source: Field Survey, 2000.

Only 14% households gave their opinion in favour of having water filtering technique. They also told that NGO's have mainly given (about 82% households of the households who have the technique and have viewed) financial and technical support to have the water filtering instruments to the suffering people in the study area. Governmental Organizations have also taken their role in this context (about 11% households of the households who have the technique and have viewed). A notable proportion of the households (about 7% of that households) have adopted the technique by their own initiatives (**Table-32**).

6.3.10 The Advising Condition not to Drink Arsenic Contaminated Water .

The people of the study area are depended on tubewells for drinking water traditionally like other rural people of Bangladesh. It is found from the survey that most of the people in the study area (85% of the total households) are informed about the presence of arsenic in tubewell water and they are informed not to drink arsenic contaminated water. They are mainly informed by the NGOs (78% households of the informed households who have viewed). The Government organizations have also set forth their activities (22% households of the informed households who have viewed) to make aware the people about arsenic contamination in tubewell water in the study area (**Table-33**).

Table-33. Information about the Advising Condition not to Drink Arsenic Contaminated Water:

Advising condition not to drink arsenic affected water	Freq.	%	Advising by			
			GO		NGO	
			Freq.	%	Freq.	%
Advising	170	85	38	2235	132	77 65
Do not advising	30	15				
Total	200	100				

Source : Field Survey, 2000

6.4. Information about Health Condition in the Study Area :

6.4.1 Arsenic Affected Condition in the Family Member of the Household

Although 98 5% tubewells in the study area are arsenic affected (**Table- 27**) and most of these tubewells (9 1 %) are using frequently as sources of drinking and cooking water (**Table-9 in the Appendix**), but a very few number of people (6.5% households view) are found arsenic affected.

Table-34. Information about Arsenic Affected Condition in the Family Member of the Household.

Condition of the family member	Frequency	Percentage
Arsenic affected	13	6.50
Not Arsenic affected	187	93.50
Total	**200**	**100**

Source: Field Survey, 2000.

They are suffering from fracture spot 'in hand i.e keratosis (61.5% of the total affected persons), foska in hand i.e. non-pitting oedema (23.10/o), infection in leg i.e. gangrene (15.4%) etc. due to arsenic affect (**Table-35**). The above symptoms in the body of the affected persons are identified within a year (53.7%) and in some cases from above one year (46.2%).

Table-35. Information about the Condition of sufferings of the Arsenic Affected People.

Types of Sufferings	Duration of Sufferings								Total	
	1 month		2 months		3months-1 year		1 Year+			
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Keratosis	1	7 7			3	23	4	30.7	8	6 15
Non-pitting Oedema	1	7 7					2	15.4	3	23.1
Gangrene	2	15.4							2	15.4
Total	4	30.7			3	23 1	6	46.2	13	100

Source: Field Survey, 2000.

So, it can be said that health effect of arsenic in human body in the study area are found in very recent time. It is also found that most of these arsenic affected patients (92% of the total arsenic affected patients) in the study area did not take any treatment (**Table-12 in the Appendix**). Rest of the patients (8%) took treatment from local doctors (61.54%) and also from NGO workers (38.46%) in the study area (**Table-13 in the Appendix**). From the survey it is found that some people also died from arsenic affect (1.5% households have given their opinion).

6.4.2 Malnutrition and Arsenic Affect :

From the survey it is found that 13 people (6.50% of the respondents) are arsenic affected and they are suffering from karatosis, non-pitting oedema, gangrene etc. Among them 3 patients (23.07% of the total arsenic affected patients in the study area) have died. It is also revealed that most of the suffering people (100%) are living below poverty line 46.15% of them are below hard core line and 53.85% are above hard core line but below poverty line (**Table-36**).

Table-36 : Information about income, cost for food and calorie intake of the family of the arsenic affected patients.

Income Group (Tk.)	No. of Arsenic Affected Family	No. of family members of each family	Cost for food per month/family (Tk.)	Cost for food per person/day (Tk.)	Estimated caloric intake status (per day/person in ki/cal
0-1000	1 } = 2	4	800	6 66	<1800 i.e. below hard core poverty line.
	1	5	800	5.33	"
1001-2000	3	4	1500	12.5	1800^{+} - 2250 i.e. below hard core poverty line.
	I } =8	5	1700	11 33	"
	4	6	1600	8.88	< 1800
2001-3000	1 } = 3	5	2000	13 33	1800^{+} - 2250
	2	6	2400	13.33	"

Source : Field survey, 2000 and Bangladesh Journal of Nutrition, 1992.

These poor people usually suffer from malnutrition which reduce the body resistance power and easily facilitates the occurrence of arsenicosis So it can be said that malnutrition is one of the important health factor to be affected by arsenic.

Table-37 : Information about the relations between poverty level and arsenic affect.

Calorie Intake status of the family of the arsenic affected patients	No. of family	%
Below Hard Core Line	6	46.15%
Above Hard Core Line	7	53.85%
Below Poverty Line	13	100%

Source : Field Survey, 2000.

In our country poor people usually suffer from malnutrition which reduce the body resistance power and easily facilitates the occurrence of diseases. It is found from the survey that poor people (0-1000 Tk. income group per month) in the study area are the major victims (100%) (**Table- 37**). So it can be said that malnutrition is one of the important health factor to be effected by arsenic.

6.4.3 Working Condition of the Arsenic Affected Patient:

It is found through the field survey that a little proportion of the people (6.5%) in the study area are arsenic affected (**Table-34**). Maximum of these arsenic affected patients (76.9%) are working normally. But some of them can not work (7.7%) due to its adverse affect on body, some are deprived from work (7.7%) and some are socially neglected (7.7%) thinking it as contagious disease (**Table-14 in the Appendix**).

6.4.4 Condition of Availing Health Service Facilities and the Providers of Facilities:

Knowing the health condition of the people in the study area was one of the important attempts of the study through questionnaire. Most of the households (95% of the households) have given

Table-38. Information about the Condition of Availing Health Service Facilities and the Providers of Facilities.

Condition of availing health service facilities	Freq.	%	Health Service Provided by			
			GO		NGO	
			Freq.	%	Freq.	%
Get	11	5.50	5	45.45	6	54.54
Do not get	189	94.50				
Total	200	100				

Source: Field Survey, 2000.

their view that they do not get health service facilities either from the Government or from any other NGO's. Only 5% households have given their opinion that they get health services both from GO (45% of the households) and NGO (55% of the households).

6.5. Information about Alternative Sources of Safe Drinking Water :

6.5.1 Existing Alternative Sources of Safe Drinking Water in the Study Area :

From the survey, it is found that 98.5% tubewells are arsenic affected (**Table-27**) and 10% of the households do not avail tubewell water (**Table-26**) for drinking or any other purposes. It is also found that there are some alternative sources of safe drinking water in the villages of the study area and they are deep tubewell, pond, pitcher filter, pond sand filter, rainwater harvesting reservoir. People avail water from these sources. But the most depending source of water is pond in the study area and in average five ponds are found (80.86%) in each village in the study area.

Table-39. Information about the Existing Alternative Sources of Safe Drinking Water in the Study area.

No. of water source	Deep Tubewell		Pond		Pitcher Filter		Pond sand Filter (PSF)		Rainwater Harvesting reservoir	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0-2	62	65.96	57	40.43	4	100	10	100	57	100
3-5	28	29.79	57	40.43						
6-8	4	4.25	14	9.93						
9-11			4	2.83						
12-14			4	2.83						
15-17			2	1.42						
17+			3	2.13						
Total	94	100	141	100	4	100	10	100	57	100

Source: Field Survey, 2000

Drinking Condition of Water of the Existing Sources :

It is found through the survey that the major existing drinking water sources in the study area are tubewells and ponds. It is also found that people depend on river, canal and on newly installed water options like Pond Sand Filter (PSF), Rainwater Harvesting (RWH) for the same purposes.
It is an attempt of the study to know the drinking condition of water of the existing sources in the study area. It is revealed that tubewell water is mainly used (87.21% households of the total households view) for drinking (44.03%) and cooking (43.18%) purposes (**Table-21**). 90% people in the study area usually avail tubewell water (**Table-21**). But most of the people's (90.5%) view is that the tubewell water in the study area is not drinkable due to arsenic affected (**Table-27**).

Through the survey it is found that pond water in the study area is not drinkable (87% households view). But pond is the second prior source of water in the study area (**Table- 21**) in normal situation and even in any adverse condition.

Different Governmental and non-governmental organizations have taken programs to mitigate the arsenic contamination problem in tubewell water in the study area. Rainwater Harvesting

(RWH) and Pond Sand Filter (PSF) are the two recent water options. It is evident that water from PSF is 100% drinkable **(Table-40).** On the other hand, the harvested rainwater by recent technology is not fully drinkable. According to the survey information, 53% people in the study area seem that water from harvested rainwater is drinkable.

Table-40. Information about the Drinking Condition of Water of the Existing Sources.

Existing Water Sources	Drinking condition			
	Drinkable		Not Drinkable	
	Freq.	%	Freq.	%
Tubewell	19	9.5	181	90.5
Deep Tubewell	41	84	8	16
Pond	26	13	174	87
Rainwater Harvesting	19	53	17	47
Canal	2	5	40	95
River	-	-	5	100
PSF	10	100	-	-
Other	1	50	1	50
Total				

Source: Field Survey, 2000

Relative Distance of the Existing Sources of Drinking Water from the Houses of the Households :

From the survey it is found that most of the tubewells (71.5% of the total tubewells within the survey area) are located within 10 meters from the houses of the households. Moreover, about 82.5% tubewells are located within 15 meters from the houses of the dwellers in the study area.

On the other hand, maximum ponds (69% of the total ponds) in the study area are located within 15 meters from the house of the households. Deep tubewells are also located within ½ km of their houses. There are also canal and river within 1/2 km. from their houses. From the above information it can be said that the tubewells rather than other sources of drinking water are located very nearer to the houses of the households Although the people are concerned that 98.5% tubewells are arsenic affected **(Table-27),** the proximal distance of tubewells from the residences of the households makes the people psychologically bound to collect and to frequently use of tubewell water for different purposes.

Table-41. Information about the Relative Distance of the Existing Sources of Drinking Water from the Houses of the Households.

Water Sources	Distance of the existing sources of drinking water from the houses of the households.													
	(0-2) m		(3-5) m		(6-8) m		(9-11) m		(12-14) m		15m- ½ km		½ km+	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Tubewell	21	10.5	61	30.5	24	12	37	18.5	19	9.5	32	16	6	3
Deep TW	1	.5	2	1	3	1.5	4	2	1	.5	73	36.5	116	58
Pond	13	6.5	34	17	30	15	35	17.5	26	13	59	39.5	3	1.5
HRW	2	5	2	5	-	-	-	-	-	-	1	2.5	31	86
Canal	1		1		4		2		1	-	23	-	22	
River	1				2		1		-	-	4		3	

Source: Field Survey, 2000

6.5.2 Condition of Availing Safe Drinking Water :

It is revealed from the survey that only 22 percent people can avail safe drinking water from different sources like Ponds (20.45%), Deep tubewells (31.82%), Harvested Rainwater (9.09%), Pitcher filter (4.58%), Pond Sand Filter (18.18%) and most of the people (78% of the Household) are deprived from safe drinking water. It is also revealed that the Governmental Organizations are taking vital role (70% households view) to provide safe drinking water to people of the study area **(Table-32).** Non governmental organizations also set forth their programs individually (24.5% households view) and jointly (5.5% households view) with the governmental organizations for its remedy **(Table-17 in the Appendix).**

Table-42. Information about the Condition of Availing Safe Drinking Water.

Condition of availing safe Drinking Water	Freq.	%	Sources of Safe Drinking Water: Pond Freq.	Pond %	Deep T. W. Freq.	Deep T. W. %	R.W.H. Freq.	R.W.H. %	Pitches Filter Freq.	Pitches Filter %	Pond Sand Filter Freq.	Pond Sand Filter %	Other Sources Freq.	Other Sources %
Avail	44	22	9	20.45	14	31.82	4	9.09	2	4.54	8	18.18	5	11.36
Not Avail	156	78												
Total	200	100												

Source: Field Survey, 2000

6.5.3 Availability of Water in the Existing Water Sources :

From the survey it is found that the existing water sources in the study area are the tubewells (100% households opinion), ponds (100%), deep tubewells (33%), canal (32.5%), harvested rainwater (13%) and river (3.5%). It is also evident that water prevails in tubewells (96% households opinion), in ponds (90.5%), in canal (58.46%), in river (57.14%) and in the harvested rainwater reservoir (3.85%) for 9 months and above, i.e. through out the whole year **(Table-43)**. So it can be said that water is available in the existing sources through out the year in the study area.

Table-43. Information about the Availability of Water in the Existing Water Sources.

Existing water sources	Freq.	%	Availability of water in the existing water source: (0-2) months Freq.	(0-2) months %	(3-5) months Freq.	(3-5) months %	(6-8) months Freq.	(6-8) months %	and above (9-11) months Freq.	and above (9-11) months %
Tubewell	200	100	2	1.00	3	1.50	3	1.50	192	96.00
Deep Tubewell	66	33	1	1.51	6	9.09	22	33.33	37	56.06
Pond	200	100	-	-	5	2.50	14	7.00	181	90.50
Harvested Rainwater	26	13	18	69.23	4	15.38	4	15.38	1	3.85
canal	65	32.5	-	-	-	-	27	41.54	38	58.46
River	7	3.5	-	-	-	-	3	42.86	4	14
Total	564	100	-	-	-	-	-	-	-	-

Source: Field Survey, 2000

6.5.4 Condition of Rainwater Harvesting Technique in the Study Area:

Rainwater harvesting is an old and very familiar technique in the rural areas of Bangladesh. The rural people usually collect water in their pitchers & 'motka' when it is raining. This water is used mainly for domestic purposes and rarely for drinking purpose for a very short time. Community based well developed harvesting technique is adopted in very recent time in the rural areas specially in the arsenic affected areas of Bangladesh. This is the latest but very expensive technique in context of socio-economic condition of the rural people of Bangladesh for getting safe drinking water. Throughout the survey it is found in the study area that 36 households (18% of the total households) have responded in favour of existing rainwater harvesting technique within their proximity.

6.5.5 Time of Harvesting Rainwater by the Households themselves :

Through the snrvey it is found that 90% people in the study area do not harvest rainwater during rainy season to get safe drinking water and only a few number of families (10% households) avail water from this new technology. It is also known that the households have adopted this technology very recently. Most of the rainwater harvesting spots (80% of the total spots) have installed within the last 2 months.

According to the survey information, it can be said that 45% of the adopted harvesting techniques were set up in one month ago from the time of survey in the study area. In addition, 35% rainwater harvesting techniques were set up 3 months ago. 5% people of the total rainwater harvesters collect rainwater in traditional method during rainy season **(Table-20 in the Appendix).** The harvested rainwater from newly adopted technology can be used for one month (62.5% Household's opinion) or for 3 months (62.5%) or for 5 months (75%) as drinking water **(Table-44).**

Table-44. Information about the time of Harvesting Rainwater by the Households themselves:

Condition of Harvesting Rainwater	Freq.	%	Time of Harvesting Rainwater by the households							
			1 Month		2 Months		3 Months above		Harvest in Traditional System	
			Freq.	%	Freq.	%	Freq.	%	Freq.	%
Harvest	20	10	9	45	7	35	3	15	1	5
Do not harvest	180	90								
Total	**200**	**100**								

Source: Field Survey, 2000.

6.5.6 Purpose of Use of Harvested Rainwater (in priority basis) :

It is also found that the harvested rainwater is used for different purposes like drinking (38.5%), cooking (3 8.5%), washing (2%) and other (2 1%) purposes. Among the above purposes, the users use this water mainly for drinking (100% households opinion for the first priority) and then for cooking (100% opinion for the 2nd priority) purposes.

Table-45. Information about the Purpose of Use of Harvested Rainwater (in priority basis).

Purpose of use of Harvested Rainwater	Freq.	%	Priority Ranking of use of Harvested water			
			1		2	
			Freq.	%	Freq.	%
Drinking	20	38.5	20	100	0	0
Cooking	20	38.5	0	0	20	100
Washing	1	2				
Others	11	21				
Total	**52**	**100**				

Source : Field Survey, 2000.

6.5.7 Assisting Authority to exist the Rainwater Harvesting Technique :

There are several rainwater harvesting tanks in the study area set up mainly by the nongovernmental organizations (91.5%) and also by the governmental organizations (8.5%) to provide safe drinking water ((**Table-21 in the Appendix**). It is also known that each tank costs 12,000/- to build up. In case of selecting the location of the tanks the following things were considered

1. The roof of the houses are built with relatively new C.I. sheets.
2. Maximum people can get water traveling minimum distance.

It is also found that maximum roofs of the houses (96%) in the study area are built up with C.I. sheets. So the rainwater harvesting technique can easily be setup if other financial and material supports available. So it can be said that the roof condition of the houses in the study area are favourable to setup Rainwater Harvesting Technique.

6.6 Information about the Problems Related to Safe Drinking Water :

The people of the study area are suffering from different problems related to availing safe drinking water. On the ranking basis the problems are scarcity of safe drinking water, people are worried about their fate, safe drinking water sources are far away from the houses, health effect due to drink arsenic contaminated water, people are bound to drink arsenic contaminated water, pond water in impure, deep tubewells are often disordered, insufficient number of tubewells, water purification method in costly, lack of water purifying instruments, water in the pond dose not stay in all seasons, arsenic affected people are socially neglected, tubewell water is red i.e. high concentration of iron in water, collection of water from a long distance hampers the normal activities of the housewives, safe drinking water collection is difficult during rainy season, arsenic contamination problem is a terrible problem, filtered water is not tasty, water is not available from harvested rainwater reservoir when rain does not occur, people can not drink harvested rainwater due to odor of cement in water, quantity of arsenic in tubewell water is not known accurately, lack of reservoirs for collection of rainwater, people are annoyed with GO & NGO's activities etc.

Table- 46.Information about the Problems Related to Safe Drinking Water.

Sl. No.	Problems	Freq.	%
1.	Scarcity of safe drinking water	120	35.82
2.	People are worried about getting safe drinking water	60	17.91
3.	Safe drinking water sources are far away from the houses.	49	14.63
4.	Health effect due to drink arsenic contaminated water	19	5.67
5.	People are bound to drink arsenic contaminated water	16	4.78
6.	Pond water is impure	15	4.48
7.	Deep tubewells are often become inactive or difficult to operate	10	2.99
8.	Insufficient number of tubewells	10	2.99
9.	Alternative Safe Water options are costly to adopt	6	1 79
10.	Alternative Safe Water options are insufficient	5	1 49
11.	Water is not available in the pond in all seasons	4	1.19
12.	Arsenic affected people are socially neglected	3	89
13.	Tubewell water is reddish in colour i.e. high concentration of iron in water	3	.89
14.	Safe water collection from a long distance hampers the activities of the housewives	2	.6
15.	Safe drinking water collection is difficult from ponds and rainwater harvesting reservoirs	2	.6
16.	Arsenic contamination problem is a terrible problem	2	.6
17.	Filtered water from pitcher filter, charri filter and pond sand filter is not tasty	2	.6
18.	Water is not available from harvested rainwater reservoir when rain does not occur	2	.6
19.	People can not drink harvested rainwater due to bed odor of cement in water	2	6
20.	Quantity of arsenic in tubewell water is not known accurately	1	29
21.	Lack of reservoirs for collection of rainwater	1	.29
22.	People are annoyed with GO & NGO's activities	1	.29
	Total =	335	99.99

Source: Field Survey, 2000.

CHAPTER : 07

Findings & Recommendations

CHAPTER 07: FINDINGS & RECOMMENDATIONS OF THE STUDY

7. Findings & Recommendation :

7.1 Findings :

On the basis of analysis of questionnaire survey on '**Alternative Sources of Safe Drinking Water for the Arsenic Affected Areas in Kachua Thana of Chandpur District**', some generalizations are formulated. Moreover, a total scenario relevant to the arsenic contamination problem in tubewell water is revealed. It is found that most of the people (86%) in the study area get sufficient water from the existing water sources through out the year. The existing water sources are tubewells and ponds. Tubewells are not homogeneously distributed in relation to the number of families in each of the village in Kachua Thana of Chandpur District. Tubewell water in the study area is used for drinking (77.5%) and cooking (76%) purposes. In fact, the people do not face trouble (82%) with quantity of water from these tubewells. But it is their misery that all most all tubewells (98.5%) are arsenic affected. Arsenic, the renowned toxic element for human health, is concentrated in water of these tubewells at high level and in some cases at more than permissible level, i.e. .50 mg/L. The wells are marked (98.5%) with red and green colors which indicate the tubewell are arsenic affected and are not arsenic affected respectively. Although water of these tubewells (90.5%) are not drinkable and people are concerned (60.5%) about this, but people are using (98.5%) water from these contaminated tubewells for drinking, cooking and other purposes. The lack of adequate number of safe drinking water options is the prime reason of use of contaminated tubewell water by the people in the study area. Consequently there is huge number of ponds in the study area aud they are used as the second prime source of water for both drinking and cooking purposes in normal and even in adverse situation. But pond water is not drinkable (87%) at all. Moreover, a few number of people are found arsenic affected and no significant health service facilities are promoted (95%) in this disaster prone area by the governmeutal and non governmeutal organizations. The arsenic affected patients can not work (7.7% of tbe total patients), do not get work (7.7%) and are socially neglected (7.7%). To combat the situation, some new water options are found to promote by both governmental and non-governmental organizations at a very small scale in the study area. Among the water options 3-pitcher filter technique is comparatively less costly and comparatively popular than rainwater harvesting technique. Pond sand filtering is also found to adopt at a very small number in the study area. Thus new techniques are innovated and are trying to set up for the remedy of the problem.

7.1.1 General Condition of the Existing Water Sources

1. The existing water sources in the study area are the tubewells (100%), ponds (100%), deep tubewell (33%), canal (32.5%), harvested rainwater (13%) and river (13%).
2. In general, pond is the most depending sources (54.50%) and tubewell is the second prior sources of water (41.71%) in the study area.
3. Water prevails throughout the year in the existing sources in the study area like tubewells (96%), ponds (90.5%), canal (58.46%), river (57.14%) and in the harvested rainwater reservoir (3.85%).
4. Most of the people of the study area (about 86% of the total households) get sufficient water from the existing water sources throughout the year.
5. People at a very low rate (18%) do not get sufficient water from the existing tubewells. They avail water in the crucial time from different sources like ponds (91.18%), river and canal (2.94%).
6. A little proportion (14%) of the total households is suffering from scarcity of water from the existing sources in all the seasons (6%) or for a few time of the year (8%).
7. Most of these suffering people (80%) avail water from ponds within their proximity when the water scareity sitnation prevails in the study area.

7.1.2 Tubewells :

1. About 82.5% tubewells are located within 15 meters from the houses of the dwellers in the study area.
2. There in no homogeneity in distribution of tubewells in the study area in context of family numbers.
3. 1-6 families depended or a single tubewell is the maximum family group (67%) in the study area.
4. Almost all tubewells (9 1 %) are using for collection of water for different purposes.
5. About 90% people of the study area are to depend on tubewell water for drinking or other purposes.
6. People of the study area generally avail tubewell water for drinking (77.5%) and cooking (76%) purposes.
7. Majority of people (83% of the total households) do not get arsenic free water in the study area.

8. The crisis of safe drinking water prevails in the study area. Only 22% people can avail safe drinking water from ponds (20.45%), deep tubewells (31.82%), harvested rainwater (9.09%), pitcher filter (4.5 8%), pond sand filter (18.18%) etc.
9. To detect arsenic in tubewell water in the study area, maximum water test were conducted by the non-governmental organizations (75% of the total tests).
10. The people in the study area are not facing trouble (82%) with quantity of water from the existing tubewells for drinking and other purposes.
11. Almost all tubewells (98.5%) in the study area are arsenic affected.
12. Maximum people (60.5%) of the study area could come to know the presence of this toxic element in tubewell water in the study area within the last one year from the survey date (April, 2000).
13. Water from most of the tubewells (90.5%) is not drinkable due to arsenic affect in the study area.
14. Maximum tubewells (98%) are arsenic affected and most of them (91% of the affected tubewells) are using for cooking and drinking purposes.
15. Maximum tubewells (98.5%) in the study area are marked with red (arsenic contaminated) or green (not arsenic contaminated) colors.
16. 99% of the red marked (i.e. arsenic contaminated) tubewells are frequently used by the people.
17. Tubewells rather than other sources of drinking water are located very nearer to the houses of the households. It makes the people psychologically bound to drink arsenic contaminated tubewell water in the study area.

7.1.3 Ponds:

1. Maximum ponds (69% of the total ponds) in the study area are located within 15 meters from the houses of the households.
2. Although pond is the second prior source of drinking (26%) water in the study area, in normal situation even in any adverse condition, but its water is not drinkable (87%) at all.

7.1.4 Rainwater Harvesting Technique:

1. Most of the people (90%) do not avail water from harvested rainwater reservoirs. It is a very new water option initiated in the study area.
2. Two basic phenomena are considered by the authority to select the location of rainwater harvesting reservoir in the study area and they are: roofs built with C.I.

sheet and minimum distance from the houses but maximum opportunity to avail water from the reservoirs.

3. The rainwater harvesting reservoirs are set up mainly by the non-governmental organizations (91.5%). Each reservoir costs Tk. 12,000.00 to build up.
4. The harvested rainwater is mainly used for drinking (100%) and cooking (100%) purposes.
5. The harvested rainwater from developed technology can be used hardly for 5 months (75%).
6. People get water for drinking and cooking purposes from rainwater harvesting reservoirs and from pond sand filter (PSF) at a very low rate (2% and 1% respectively).
7. Maximum roofs of the houses (96%) in the study area are built with C. I. sheets.
8. The roof condition of the houses in the study area is favourable to set up rainwater harvesting techniques.

7.1.5 Health Effect :

1. Maximum people (95% of the total households) in the study area do not get health service facilities in relation to the arsenic affect either from the governmental organizations or from any other NGOs.
2. A very few number of people (6.5%) are found arsenic affected in the study area. They are suffering from Keratosis, Non-pitting Oedema and Gangrene etc.
3. Most of the arsenic affected patients in the study area (92% of the total arsenic affected patients) did not get any treatment and rest of them got treatment support from local doctors (61.54% of the people who got help) and from NGO workers (38.6% of the people who got help).
4. Majority of the arsenic affected patients (76.9 1 %) as found, are working normally.
5. Some patients can not work (7.71% of the total patients), some are deprived from work (7.7%) and some are socially neglected (7.7%).
6. The burning problems created due to the arsenic affect in the study area are:
   a) Scarcity of safe drinking water;
   b) People are worried about their fate.
   c) Safe drinking water sources are insufficient and located far away from the houses.

7.1.6 Role of GO's & NGO's:

1. Most of the people (74% of the total households) are noticed by the non-governmental organizations (NGO's) about the presence of arsenic in tubewell water, negative health consequences of arsenic and procedures to get arsenic free water.
2. Mainly NGO's informed (75%) the people about the presence of arsenic in tubewell water in the study area. The governmental organizations are taking vital role (70%) to provide safe drinking water to the people of the study area. Non-governmental organizations individually (24.5%) and jointly with the governmental organizations are (5.5%) working for its remedy.
3. Among the new sources of safe drinking water promoted by different governmental and nongovernmental organizations in the study area, water from Pond Sand Filter (PSF) is 100% drinkable. But water from Rainwater Harvesting Reservoirs (RHR) is not fully drinkable (53%) due to odor of cement.
4. To get arsenic free water, only 14% people in the study area are using water-filtering techniques. Maximum of the instruments (82%) are provided by the NGO's.

7.2 Recommendations : The following steps may be recommended to encounter the arsenic hazard :

7.2.1 Immediate Relief Measures:

7.2.1.1 Recommendation-1 : Build Awareness Through Mass Communication :

- Intensive awareness raising activities should be undertaken immediately regarding negative health effects of drinking arsenic-contaminated water in order to introduce preventive measures in cooperation with community based organization (CBOs), NGOs and others. Mass media and communication facilities of government and non-government organization should be initiated for awareness. Specific posters, leaflets and other communication materials should be developed for this purpose.
- To make the people aware about arsenic contamination and its health effects training program should be arranged specially for female members of the family in the arsenic affected areas.

7.2.1.2 Recommendation-2: Providing Safe Drinking Water

Immediate relief on emergency basis should be provided through the supply of safe drinking water. In selecting the source of supply of safe drinking water, the following order of preference may be followed:

- Only tubewells with safe drinking water may be used.
- Deep tubewells may be installed by avoiding shallow arsenic contaminated aquifers to collect water of acceptable quality in the arsenic affected areas.
- Dug wells may be constructed where feasible to supply arsenic free water.
- Surface water can be used with appropriate and adequate treatment. Surface waters may be treated by installation Slow Sand Filter (SSF) if perennial sources of water are available in arsenic affected areas. Community participation in operation and maintenance is absolutely essential to make the system work.
- At least a pond protected from contamination should be provided in each mauza in the study area for drinking purposes. Minimum treatment would be required initially. Other ponds would be provided for different purposes without treatment. The protected ponds shall not receive any surface discharges and should be replenished by rain and ground water infiltration.
- At least one Pond Sand Filter (PSF) should be installed in each village to provide cooking and drinking water in the arsenic affected area. This may be done by a GO or NGO but maintained by the community people.
- Rainwater harvesting can be a source of water supply for drinking and cooking purposes. For this purpose, at least one rainwater harvesting reservoir should be constructed in each village in the arsenic affected area by GO or NGO. The location would be selected in such place from where maximum people can collect water from it.

7.2.1.3 Recommendation-3: Providing Medical Care at Health Canters for Seriously Affected Patients

Treatment facilities should be available at the health centers for the seriously affected patients. Support needs to be made available for this purpose from NGOs and from international agencies.

7.2.1.4 Recommendation- 4: Providing Symptomatic Treatment :

The immediate action for providing symptomatic treatment should be included and should be taken care of skin problems. Serious problematic patients should be referred to health centers or regional hospitals.

7.2.1.5 Recommendation-5: Strengthening diagnostic facilities at regional level :

Many cases of arsenic poisoning are easy to diagnose. In more complicated cases, laboratory facilities will need to be improved at the regional level to determine the arsenic levels in water as well as human tissues. For this, funds need to be made available from international agencies (e.g. WHO, UNICEF, UNDP & the World Bank).

7.2.2 Long Term Measures :

7.2.2.1 Recommendation-6: Strengthening Inter-ministerial Co-ordination & Cooperation

A national apex committee should be formed to strengthen national level inter-ministerial coordination to address arsenic contamination of drinking water.

7.2.2.2 Recommendation-7: Establishing National Database on Arsenic in Drinking Water & Resulting Arsenic Toxicity :

Document of the extent of the problem should be collected and all the requisite information related to drinking water supply and health problems should be generated and should be evaluated the data.

7.2.2.3 Recommendation-8: Reviewing Existing Arsenic Removal Technologies & Evaluating their Efficiency :

A review and evaluation of the arsenic removal treatment technologies and their efficiency should be undertaken.

Conclusions :

Arsenic problem in Kachua is a part of the problem in context of Bangladesh. It is a great natural and national calamity. This problem is concentrated in the rural areas where about 76% of the people are living and where the tubewells supply water from the shallow aquifers has been found to be contaminated with arsenic. A number of institutions, universities, governmental and nongovernmental organizations and donor agencies including World Bank are working on various aspects of arsenic contamination of ground water. Several projects have been undertaken to understand the magnitude of the problem even in Kachua and to adopt mitigation measures but it appears to be the beginning of addressing the problem nationwide. An extensive works would be required to understand the sources, causes, occurrences and distribution of arsenic contamination, health effect and health management, communication of health impact and finally development and implementation of safe water supply options in arsenic affected areas. A close coordination of all initiatives in resolving this gigantic problem is needed for effective and efficient utilization of resources to attain the common goals. Thus a coordinated plan is intended to provide a basis for collaboration of the actors in the field and mobilize the efforts in the right direction even in village level. Results of different studies in some areas in Bangladesh have revealed that water from deep wells has not yet been contaminated with arsenic. But groundwater being a rechargeable resource, excessive withdrawal of groundwater from deep aquifers may have adverse impacts both in the deep as well as the shallow aquifers. Bangladesh is blessed with ground water resource but it is not unlimited due to the complex hydro-geological conditions. The problem of contamination of ground water by arsenic or other toxic element is gigantic and complex. Considering the water resources available on the surface and in the sub-surface, it is recommended that people in the affected areas have to choose one of the four options offered to get arsenic free water. The options are sinking of deep tubewells, the excavation of wells, digging new wells and installation of locally developed technology including Pitcher Filter, Bucket Filter and 'Pond-Sand-Filter' on the bank of ponds. The PSF will also purify pond water from bacteria and other germs.

Large-scale treatment plants to remove arsenic from water will sustainable mitigation of arsenic problem. All possible ways and means will have to be adopted to meet the immediate need to supply safe drinking water to the people in the affected areas.

Kachua, being a remote rural sub-district, requires the assistance of the government, the donor agencies and the NGOs to mitigate the gigantic arsenic contamination problem. The local people are willing to work closely with the government and the NGOs. So, by strengthening the local governance and people's participation in the village community and with the assistance of the central government, this gigantic problem may be resolved with installation of the deep tubewells in the clustered and the linear villages along with local options. This will ensure a vista of sustainable living environment in the village community.

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APPENDIX : 01

Sample Questionnaire

Department of Urban and Regional Planning

Bangladesh University of Engineering and Technology (BUET)

Questionnaire for

"A Study on Alternative Sources of Safe Drinking Water for Arsenic-affected Areas in Kachua Thana of Chandpur District"

(Questionnaire for Household Survey)

(For Research Purpose only).

1. Information about the Household/Family

1.1 Name of the village:

1.2 Name of the Mauza

1.3 Name of the Household Head:

1.4 Type of Family : (i) Single (ii) Combined (iii) Others (iv) No response

1.5 Religion : (i) Muslim (ii) Hindu (iii) Christian (iv) Buddhist (v) No response

1.6 Setting in this village : (i) Since grand father's time (ii) Since father's time (iii) Since own time (How long. --------- Year) (iv) No response

1.7 Detail information about each of the member of the household

Members		Head	2	3	4	5		7	8	9	10	11	12
Age													
Sex													
Education													
Occupation	Primary												
	Secondary												

Code: Sex : 1. Male 2. Female

Education : 1 Illiterate 2.Primary 3.Secondary 4 SSC 5.HSC 6.Graduate 7.Masters 8 Others

Occupation :1. Farmer 2 Day labourer 3.Richsaw/Van pullar 4. Push cart driver 5.Household worker 6 Mason 7 Service (Govt.) 8 Service (Private) 9. Businessman 10.Student 11. Unemployed 12. House wife 13. Others.

1.8 House hold Income (per month) :

Own : -------------------------- Taka/Month

Children/Wife: ------------------------ Taka/Month

1.9 Household Expenditure (Per Month) [please include all expenses like food, housing, clothing, utility service charge, medical, education etc.]

Family (Total): ------------------------------ Taka/Month.

2. INFORMATION ABOUT WATER SUPPLY.

2.1 We would like to know how are you using different sources of water for different purposes? (Please use tick only)

Sources of water supply	For drinking & cooking purpose	For cleaning, bathing & washing purpose	For all purpose
1. Tubewell			
2. Pond			
3. Well			
4. River			
5. Canal			
6. Others (Specify)			

2.2 Do you pay for availing water from tubewells? i Yes ☐ ii No ☐

2.3 If yes, what is the monthly cost you have to pay? [In case of daily payment and or charges based on use quantity of water, please calculate on a month basis]

i. I have to pay (monthly) ---------------------------- Taka ii. Others (Specify)

To whom you have to pay for drinking water? i. Owners of the tubewell ☐ ii. NGO ☐ iii. GO ☐ iv. Other ---------

2.4 Do you get sufficient supply of water from this tubewell? i Yes ☐ H. No ☐

If no, from where you have to collect water? i. Pond ☐ ii. Tubewell ☐ iii. River ☐ iv. Canal ☐ v. Others ------------

If no, do you have to buy/pay to meet your water requirement? i. Yes ☐ ii. No ☐

If yes, what are the extra amount you spend for your additional water requirement per month? Cost of additional Requirement-- Taka.

2.5 What is the number of users (family/person) per water source?

i. Number at present ------------------------------ ii Don't know ☐

2.6 Do you get sufficient water supply from these water sources both at dry season and wet season? i. Get sufficient water supply in all the seasons ☐ ii. Get sufficient water supply in wet season but do not get in dry season ☐ iii. Get sufficient water supply in all the seasons.

2.7 If you get sufficient water in wet season or do not get sufficient water supply in all the seasons, what are the alternative sources of water supply on those periods? From i. Pond ☐ ii. Well ☐ iii. River ☐ iv. Canal ☐ v. Depend on fate ☐ vi. Others (Specify) ----------

2.8 Do you avail tubewell water for drinking or other purposes? i. Yes ☐ ii. No ☐

If yes, what is the present condition of the water sources? ii Arsenic affected ☐ ii Not arsenic affected ☐

29. If arsenic affected, then is the tubewell running? i. Yes ☐ ii. No ☐

2.10 When arsenic is detected in the tubewell water first? ------------- years ago.

2.11 How have you informed about the presence of arsenic in the tubewell water first?

☐ By GO/NGO's water test

☐ By the symptoms of arsenic affect in the body of the users

☐ Others (specify) -----------------------

2.12 Is any body of your family member arsenic affected? i. Yes ☐ ii. No ☐
If Yes,

Persons affected	**Types of sufferings**					**Suffering from the date**
1.						
2.						
3.						
4.						
5.						

2.13 Did they take treatment? i. Yes ☐ ii. No ☐

If yes, who gave them treatment? ☐ Local Doctors, ☐ NGO, ☐ Others

2.14 Due to arsenic affect, he/she ☐ Working normally ☐ can not work ☐ does not get work ☐ socially neglected.

2.15 Has any body of your family member died due to arsenic affect? i. Yes ☐ ii. No ☐

2.16 Who has tested tubewell water of your village? ☐ GO ☐ NGO ☐ Self ☐ None

2.17 When it is tested? In the year --------------- Month -----------

2.18 Was the tubewell marked? i Yes ☐ ii No ☐

2.19 If yes, are you using water from this tubewell? i. Yes ☐ ii. No ☐

2.20 If yes, for what purpose? ☐ Drinking and Cooking ☐ Bathing ☐ Washing clothes ☐ Others

2.21 If no, who advised you not to drink contaminated water? ☐ GO ☐ NGO ☐ None

2.22 Do you get arsenic- free water? i. Yes ☐ ii. No ☐
If yes, who supply you arsenic free water? ☐ GO ☐ NGO ☐ None

2.23 Do you have water filtering instrument? i. Yes ☐ ii. No ☐

If yes, who provide you this instrument? ☐ GO ☐ NGO ☐ None

2.24 Did you/any member of your family get health service facilities? i. Yes ☐ ii. No ☐

If yes, who helped? ☐ GO ☐ NGO ☐ Local Doctor ☐ None

2.25 Are you advised to use alternative sources of safe drinking water? i. Yes ☐ ii. No ☐

If yes, who told you? ? ☐ GO ☐ NGO ☐ None

2.26 What are the exiting alternative sources of safe drinking water in your village?

Sources	No
1. Deep tubewell	
2. Pond	
3. Ring well	
4. River	
5. Canal	
6. Rain water harvesting	
7. Others	

2.27 What are the conditions of existing sources of drinking water?

Sources	Drinkable	
	Yes	No
1. Tubewell		
2. Deep tubewell		
3. Pond		
4. Ring well		
5. River		
6. Canal		
7. Rain water harvesting		
8. Others		

2.28 Relative distance of the existing sources of drinking water from the house of the household:

Sources	Distance in km.
1. Tubewell	
2. Deep tubewell	
3. Pond	
4. Ring well	
5. River	
6. Canal	
7. Others	

2.29 Do you avail safe drinking water? i Yes ☐ ii. No ☐

2.30 If yes, what is the source? ☐ Filtering, ☐ Pond sand Filter ☐ Deep tubewell ☐ Pond ☐ well ☐ River ☐ Canal ☐ Rain water Harvesting ☐ Others (Specify)

2.31 Would you have to pay for safe drinking water? i. Yes ☐ ii. No ☐

2.32 If yes, how much money per month? ---------------------

2.33 To whom you pay? ----------------------

2.34 If no, who provide you safe drinking water?

Type	Name
GO	
NGO	

2.35 How much water is needed for your family per day?

Purpose	Quantity (Litter)	Tk. (If applicable)
Drinking and cooking		
Bathing and washing clothes		
Other		

2.36 Mention the duration of water stagnation in existing sources in your village

Sources	Month
1. Tubewell	
2. Deep tubewell	
3. Pond	
4. Well	
5. River	
6. Canal	
7. Harvested Rain Water	

2.37 Is there any method or technique to harvest rainwater during wet season in the village?

i. Yes ☐ ii. No ☐

2.38 Do you harvest rainwater during wet season? i. Yes ☐ ii No ☐

2.39 If yes, from when it is going on? From the year -----------------------

2.40 How many days you can use as drinking water of this harvested rainwater? -------------

2.41 How it is cost to harvest rain water in a season? ------------------------------------- Tk.

2.42 For what purpose you are using harvesting rainwater? (Use priority ranking as described by the respondent)

Rank	Purpose
	Drinking and cooking
	Bathing
	Washing cloths
	Others

2.43 Who helped you to exist the technique? ☐ GO ☐ NGO ☐ None

2.44 Mention your roof material : ☐ Pacca ☐ Tin ☐ Straw ☐ Others

2.45 Respondent's perception of satisfaction of provided safe drinking facilities (Please use tick mark on each item/variable relevant to the level of satisfaction)

	Items/Variable	Satisfactory	Acceptable	Unsatisfactory
i.	Location of water source			
ii.	Number of water source			
iii.	Duration of water stagnation in pond			
iv.	Quality of pond water			
v.	Quality of water supply from tubewell			
vi.	Quality of tubewell water			
vii.	Accessibility of water from tubewell			
viii.	Availability of safe drinking water			
ix.	Water test by the GO/NGO			
x.	Filtering system by the GO/NGO			
A	Pond Sand Filtering System			
xii.	Training/awaring system by the GO/NGO			
xiii	Help (both serving & Financing by the GO/NGO).			
xiv	Cost for safe drinking water			
xv.	Rainwater harvesting system			
xvi	Cost for Rainwater harvesting			

2.46 Respondent's perception of problems related to safe drinking water supply facilities (Use priority ranking as describe by the respondent).

No.	Problems Related to Water Supply Facilities	Rank.
1.	Location of water source is not satisfactory	
2	No of water sources is not satisfactory	
3	Duration of water stagnation in pond is short in time	
4	Pond/well water is not pure	
5.	Safe drinking water is not available	
6.	Tubewell water is arsenic affected	
7.	Water supply from tubewell is insufficient	
8	Water purification system is not good	
9.	GO/NGO does not make aware the people	
10	GO/NGO did not promote proper action for the remedy	
11	Water filtering system is costly	
12	Water filtering system is beyond capacity	
13	Rainwater harvesting system is not existed	

2.47 Other Comments Related to Water Supply --

Thank you for your kind co-operation.

Name of the Interviewer --- Date :---------------------------

APPENDIX : 02

Tabular Presentation of Data

Tabel-1: Guide Line Values of Arsenic.

Countries	Quantity of Arsenic in per liter of water.
European Countries	.01 mg.
Australia	0007 mg.
Japan[1]	.01 mg.
Canada	025 mg.
USA[2]	..05 mg.
Bangladesh	05 mg
India	05 mg

1. This value was fixed in 1993. The earlier value was .05 mg/L.
2. The USA tries to change this value into 0.02 mg/L within the year 2002

Source : Ahmed, S A, (2000), Arsenic, Dhaka.

Table-2 : Arsenic Statistics from the National Hydro-chemical Survey (2000).

Tubewell	By Depth	Number	% Tubewell	Avg. concentration (μg/L)
Shallow tubewell	<15m	287	8	58
	15-30m	1180	33	76
	30-60m	1258	36	56
	60-90m	317	9	33
	90-150m	165	5	45
Deep tubewell	150-200m	32	1	7
	200m	295	8	3
	Total	**3534**	**100**	**55**

Source: National Hydro-chemical Survey, 2000

Table-3 : Sex Composition of the Family Members of the Households.

Sex Composition	Frequency	Percentage
Male	668	57.80
Female	484	44.20
Total	**1147**	**100**

Source: Field Survey, 2000.

Table-4 : Educational Status of the Family Members of the Households.

Education Status	Frequency	Percentage
Illiterate	175	15.29
Primary	437	38.01
Secondary	267	23.28
S.S.C	118	10.29
H. S.C.	84	7 32
Degree and Above	53	4.62
Others	14	1 22
Total	**1147**	**100**

Source: Field Survey, 2000

Table-5 : Occupation of the Household Head.

Type of Occupation	Primary occupation		Secondary occupation	
	Frequency	%	Frequency	%
Farmer	82	41	26	76.47
Day Labourer	4	2	2	5.88
House hold Worker	-	-	-	
Service Holder (Private)	17	8 50	1	2.94
Service Holder (Govt)	20	10	-	-
Business man	51	25.50	4	11 76
Student	1	0 50	-	-
Unemployed	6	3	-	-
Others	19	9 50	2	5.88
Total	**200**	**100**	**34**	**100**

Source: Field Survey, 2000.

Table-6 : Expenditure of the Household per Month (Tk.).

Expense Per Month (Tk.)	Frequency	Percentage
0-1000	1	.50
1001-2000	8	4
2001-3000	37	18 50
30014000	43	21 50
4001-5000	46	23
5000+	65	32.50
Total	**200**	**100**

Source: Field Survey, 2000.

Table-7 : Monthly Family Expenditure of the Household (Tk).

Expenditure (Tk.)	For Food		For Clothing	
	Frequency	%	Frequency	%
0-1000	28	14	141	70.50
1001-2000	48	24	35	17.50
2001-3000	62	31	19	9 50
30014000	23	11 50	3	1.50
4001-5000	19	9.50	1	.50
5000+	20	10.00	1	.50
Total	**200**	**100**	**200**	**100**

Source: Field Survey, 2000

Table-8 : Information about the Alternative Sources of Water in Case of Getting Insufficient Water at all the Seasons from the Existing Sources.

Alternative Sources	Frequency	Percentage
Pond	69	80.23
Contaminated Tubewell	1	1.16
Others	16	18.60
Total	**86**	100

Source: Field Survey, 2000

Table-9 : Information about the Condition of the Arsenic Affected Tubewell.

Condition of the arsenic affected Tubewell	Frequency	Percentage
Running	182	91
Not running	18	9
Total	**200**	100

Source: Field Survey, 2000

Table-10 : Information about the Time of Detection of Arsenic in the Tubewell Water first.

Detection of arsenic in Tubewell water before the time of survey(April,2000)	Frequency	Percentage
One Month	1	.5
Two Months	30	15
Three Months	62	31
Four Months	27	13 5
Five Months	21	10 5
Six Months	30	15
Above Six Months	29	14.5
Total	**200**	**100**

Source: Field Survey, 2000

Table-11 : Information about how the People came to know the presence of Arsenic in Tubewell Water first.

Sources of information about the presence of arsenic in Tubewell	Frequency	Percentage
By GO's water test	49	24.50
By NGO's water test	150	75
By Self Water test	1	.50
Total	**200**	**100**

Source: Field Survey, 2000.

Table-12 : Information about the Treatment Condition of the Arsenic Affected People.

Treatment Condition	Frequency	Percentage
Took Treatment	16	8
Did not take treatment	184	92
Total	**200**	**100**

Source: Field Survey, 2000.

Table- 13 : Information about the Sources of Treatment facilities Availing by the Arsenic Affected Patient.

Sources of treatment facilities availing by the arsenic affected patient	Frequency	Percentage
Local Doctor's	8	61.54
NGO	5	38.46
Total	**13**	**100**

Source : Field Survey, 2000.

Table-14 : Information about Working Condition of the Arsenic Affected Patient.

Working condition	Frequency	Percentage
Working normally	10	76.9
Can not work	1	7.7
Do not get work	1	7.7
Socially neglected	1	7.7
Total	**13**	**100**

Source: Field Survey, 2000.

Table-15 : Information about the death of the Family Member of the Household due to Arsenic Affect.

Death condition due to arsenic affect	Frequency	Percentage
Died	3	1.50
Not died	197	98.50
Total	**200**	**100**

Source : Field Survey, 2000.

Table-16 : Information about the Advising Authority not to Drink Contaminated Water.

Advising Authority	Frequency	Percentage
GO's	46	23
NGO's	148	74
None	6	3
Total	**200**	**100**

Source: Field Survey, 2000.

Table-17 : Information about the Providing Authority of Safe Drinking Water.

Providing Authority of Safe Drinking Water	Frequency	Percentage
GO	139	69 50
NGO	49	24 50
Both GO & NGO	11	5.50
Self	1	50
Total	**2**	**100**

Source: Field Survey, 2000.

Table-18 : Information about the Quantity of Drinking Water Needed per Family per day (Litter).

Quantity of Water (in Liter)	Frequency	Percentage
0 - 20	37	18.50
21 - 40	43	21.50
41 - 60	39	19.50
61 - 80	29	14.50
81 - 100	26	13
100+	26	13
Total	**200**	**100**

Source : Field Survey, 2000.

Table-19 : Information about Rainwater Harvesting Technique adopted/not adopted in the Study Area.

Condition of Rainwater Harvesting Technique	Frequency	Percentage
Adopted	36	18
Not Adopted	164	82
Total	**200**	**100**

Source · Field Survey, 2000.

Table-20 : Information about the Duration of Use of time of Harvested Rainwater as Drinking Water.

Duration of time of use of harvested rainwater as drinking water (in month)	Frequency	Percentage
0-1	6	37.5
2-3	4	25
4-5	2	12.5
5+	4	25
Total	16	100

Source: Field Survey, 2000.

Table-21 : Information about the Assisting Authority to exist the Rainwater Harvesting Technique.

Assisting Authority to exist the RWH Technique	Frequency	Percentage
GO	3	8.5
NGO	33	91.5
Total	**36**	**100**

Source · Field Survey, 2000.

Table-22 : Information about the Roof Material of the Household's Houses.

Roof Material	Frequency	Parentage
Pacca	4	2
Tin	192	96
Straw	4	2
Total	**200**	**100**

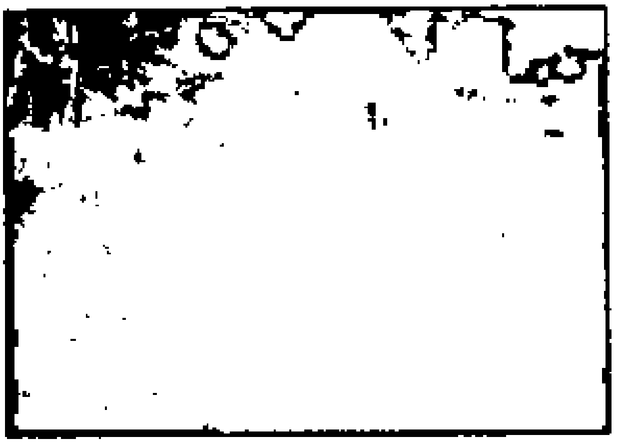
Source: Field Survey, 2000.

APPENDIX : 03

Photographic Presentation

A. Photographs of Existing Water Sources in the Study Area

01. Pond : Unprotected



02. Pond : Protected

03. Pond : Water collecting from protected pond

04. Tubewell : Water collecting from Tubewell set beside a Kacha Toilet

B. Photographs of Tubewells as the Sources of Water in the Study Area

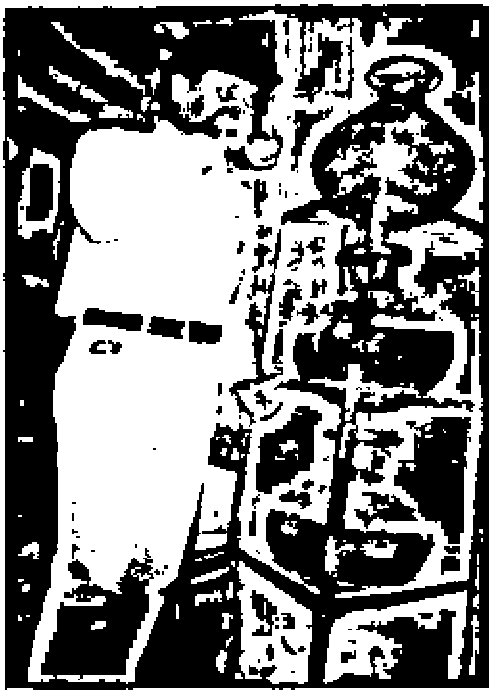
05. Tubewell : Water Test by an Expert

06. Tubewell : Arsenic Contaminated, Red Marked & Abandoned

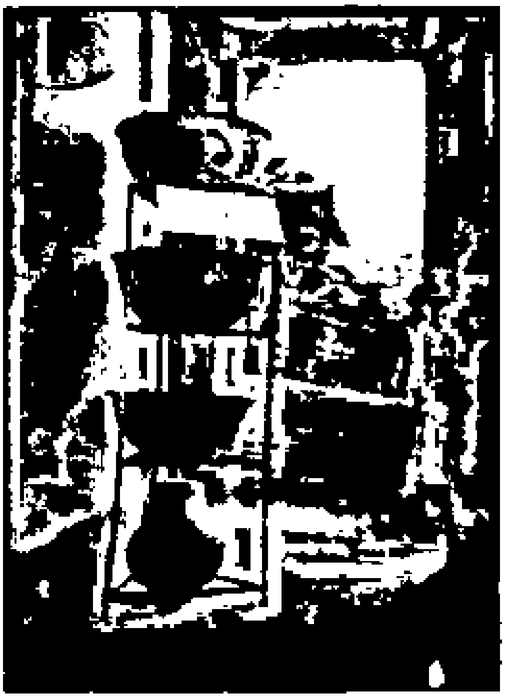
07. Tubewell : Arsenic Contaminated, Red Marked but People Collecte its Water

08. A Typical Hand Pump Tubewell : A Source of Safe Water

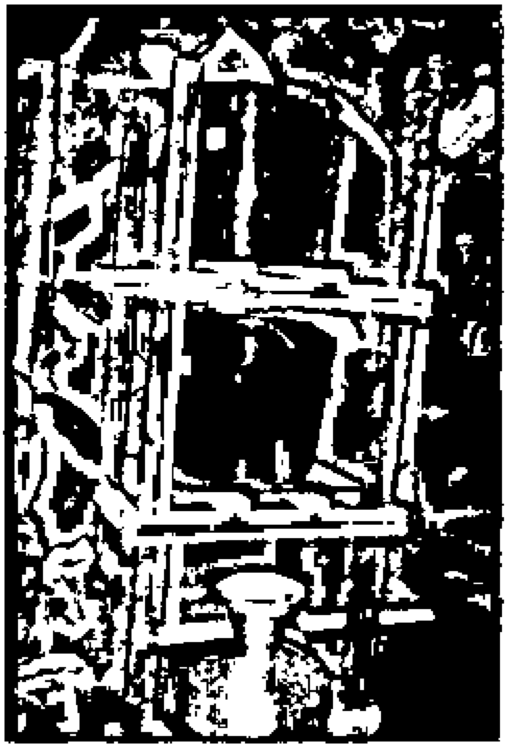
C-1. Photographs of Alternative Safe Water Sources in the Study Area



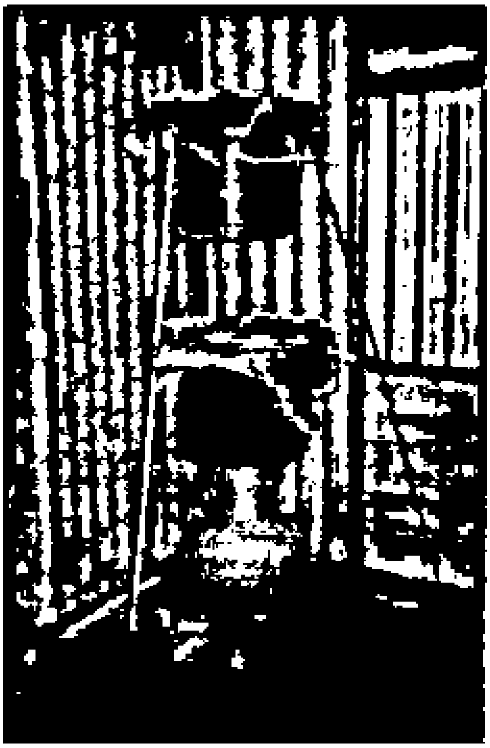
09. Four Pitchers Filter



10. Charri Filter



11. Bucket Filter with Wooden Frame



12. Bucket Filter with Steel Frame

C-2. Photographs of Alternative Safe Water Sources in the Study Area

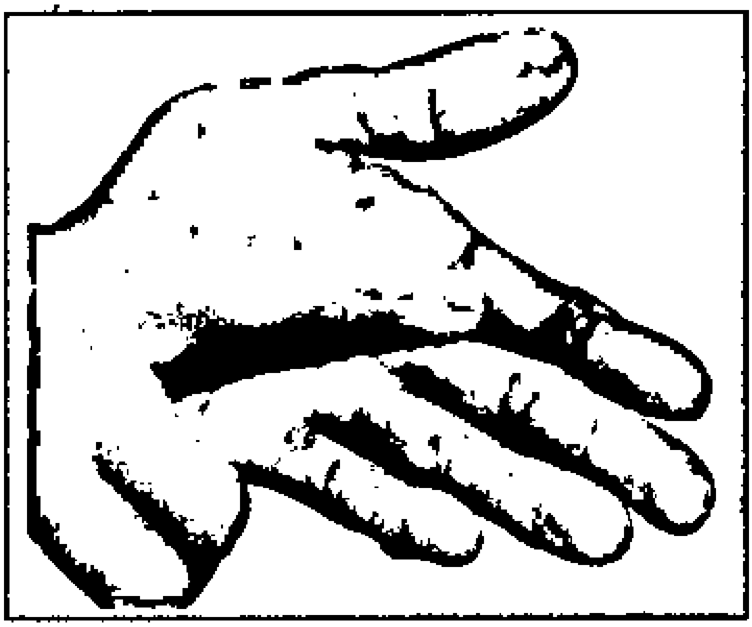
13. An Active Pond Sand Filter

14. Pond Sand Filter Constructed by Grameen Bank

15. Rain Water Harvesting Reservoir

16. An Active Rain Water Harvesting Reservoir

D. Photographs of Arsenic Affect on Health



17. Hard Swelling in Hand (Hyperkeratosis)

18. Hard Swelling in Leg (Hyperkeratosis)