GROUNDWATER ARSENIC CONTAMINATION IN RAMGONJ, LAKSHMIPUR: A GEO-ENVIRONMENTAL ANALYSIS

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Certified that Firoz Rashid has conducted the thesis work entitled "Groundwater Arsenic Contamination in Ramgonj, Lakshmipur: A Geo-environmental Analysis" under my supervision for partial fulfillment of the degree of Master of Philosophy in Geography and Environment from the University of Dhaka. The work or any part there of has not been submitted any where for any other degree.

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Abstract

Arsenic problem is now termed as one of the leading anthropogenic disaster of Bangladesh. Groundwater is extensively used for domestic, agricultural and other purposes, but presence of high concentration of arsenic in alluvial aquifer in the study area is a matter of great concern. Hundreds of people are as badly risk of arsenic poisoning in the study area. The arsenic concentration has occured due to some geochemical changes in shallow aquifer. Water levels in tubewell drop, allowing oxygen to enter the ground and touching off a reaction that leaches out arsenic from pyrite in the soil. Water and soil samples were collected and analysed for Arsenic and other parameters. Soil contains high level arsenic. Both shallow and deep tubewells have contaminated with arsenic. Seasonal variations in vertical movement of groundwater retard the contents of arsenic in the groundwater. Both field kit test and laboratory method have proved the availability of arsenic situation in groundwater. Arsenic concentration is high in outside polder than in inside polder. The lowest concentration of arsenic (0.005 mg/l) has found in deep tubewell. Among the shallow tubewells the lowest concentration of arsenic is 0.03 mg/l and the highest is 1.33 mg/l in the study area. The owner of tubewells is taking arsenic contaminated water and has been suffering in arsenicosis including cancer. Melanosis, keratosis, weakness, nail loss and hair delayed loss are also present the ansenicosis patients. Numbers of people have been suffering from a mental agony. Arsenic poisoning has been creating public health problems and as well as social and personal life. Divorce, unhappy condition in conjugal life has also observed in this study area. A good percentage of respondents see that arsenicosis is a curse of nature. Some of them are taking treatment from rural health centre.

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CHAPTER ONE

1. INTRODUCTION

1.1. General Statement of Arsenic Problem:

Arsenic is a metal often found in nature in low amounts. Groundwater arsenic contamination is a global problem now. It virtually appears on all continents. Bangladesh is grappling with the largest mass poisoning of a population in history because groundwater used for drinking has been contaminated with naturally occurring inorganic arsenic. At present arsenic poisoning is very familiare and a recently recognized in environmental problem in Bangladesh. The scale of the environmental disaster is greater than any seen before; it is beyond the accidents at Bhopal, India, in 1981 and Chernobyl, Ukraine, in 1986. Tubewells have been used in Bangladesh since the 1940s. However, the problem of arsenic contaminated water has only recently come to light due to the increasing number of tube wells used over the past 20 years and the subsequent increase in the number of individuals drinking from them. It is difficult to pinpoint the exact calendar year when poisoning first appeared in Bangladesh. But, it probably started with the onset of groundwater withdrawal schemes in the late '60s. When arsenic contamination of ground water in West Bengal of India raised storms, we were infact unaware about the poisonous element. This fact remained upto 1978. The first documented case of arsenic was reported in 1981. In 1994, one Alok Sarker of Ramnagar village in Baruispur thana of west Bengal, died of arsenic. This incident prompted the prominent researchers of Bangladesh to undertake research on arsenic contamination of ground water. It was in the year 1993 that reports of patients with arsenic-affected diseases were first obtained in the country. In Bangladesh, the first government

efforts to tackle the arsenic contamination began in 1993 when the news of arsenic contamination of ground water was detected at Samata village in Sharsha thana of Jessore district. In 1993, the Department of Public Health Engineering of Bangladesh confirmed arsenic contamination in Barughuria Union Nawabganj district. In 1994, the government formed a committee to review the situation. It was first named, "The committee for Reviewing the Situation of arsenic Toxication in Groundwater". Finally, it was renamed as Arsenic Committee. Public Health Engineering Department of the government is working in this field. There are some other non-government organizations and hospitals which are also working seriously to improve the situation. Those are National Institute of Preventive and Social Medicine (NIPSOM), Agriculture Advisory Society, Asia Arsenic Network and Dhaka community Hospital. Among them Dhaka Community Hospital is working on arsenic in collaboration with school of Environment studies and Science of Jadavpur University, United Nations Development Program (UNDP) and Ministry of Health on a population. In 1996 they detected arsenic patients in Iswardi of Rangpur and Paksi of Pabna. Then they conducted annual health camps in those areas. They have already examined the water of 12,000 tubewells in 200 thanas of 61 districts. Of them 62 per cent tubewells of 42 districts have arsenic contamination. In February 1998, the Gurdian (UK) detailed the magnitude of the arsenic contamination in Bangladesh; the local cheif of the World Bank has stated that ten millions of people are at risk, and that 43,000 villages out of 68,000 are presently are at risk or could be risk in future (DCH, 2000). In different countries, arsenic contamination in water supplies is known to have been caused by dissolving naturally occur geological deposits, from industrial discharges and from application of pesticides, chemical fertilizers and herbicides. These are not only

contaminate the soils and vegetation but also the air and nearly surface water (Nriagu and Azcue, 1990). Contamination of groundwater in Bangladesh has already been accepted as the largest among all incidence in the world and recognized as a worse disaster of this country.

In a more recent research, arsenic has been reported to be detected in 61 out of 64 districts. The latest result, in the 258 processed Upazila, total number of Tubewells are 46.37 lacs, of them 14.06 lacs tubewells are arsenic contaminated (30.32 per cent), total patients identified are 38,380. Eighty per cent and above contaminated villages are 8,546 (BAMWSP, 2004).

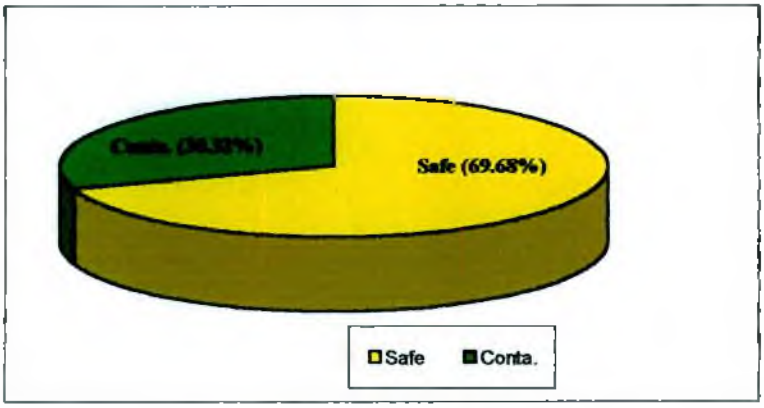
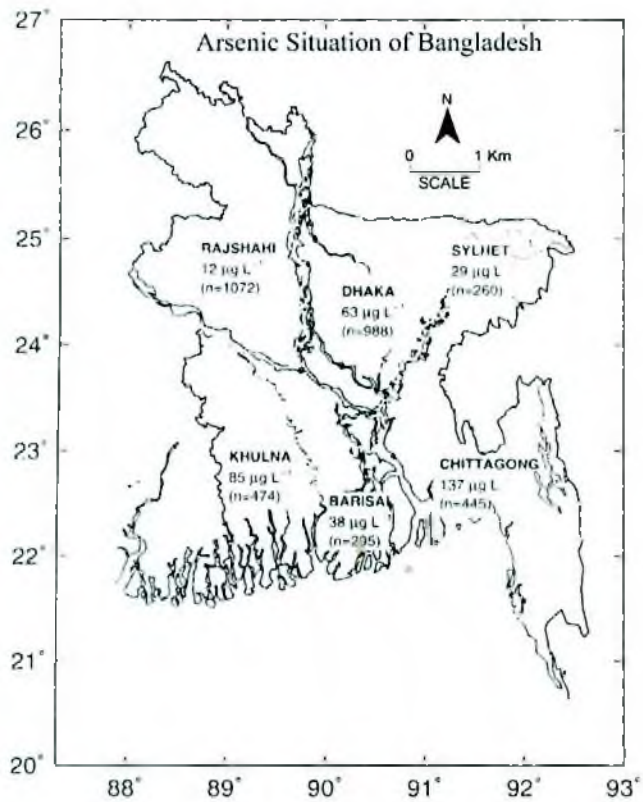


Figure-1.1 : Arsenic Contaminated Tubewells (%)

British Geological Survey (1999) based on available data on arsenic concentration in tubewell water developed a figure that provides a picture of the present situation of arsenic contamination in Bangladesh. It shows that widespread arsenic contamination in Bangladesh. According to division, arsenic affected regions are shown in table-1.1 (Appendix-A).

The tubewells in large part of Sylhet and Dhaka divisions, most of Chittagong division except the Hill tracts area significant parts of Rajshahi division and most part of Khulna and Barisal divisions except the coastal area contaminated with arsenic. Highly affected districts includes Lakshmipur, Sunamganj, Sylhet, Comilla, Brahmanbaria, Chandpur, Feni, Noakhali, Narayanganj, Gopalganj, Sariatpur, Munshiganj, Faridpur, Bagerhat, Satkhira, Khulna, Jessore, Jhenidah, Chuadanga, Meherpur, Kushtia, Pabna, Rajshahi and Chapai Nawabganj. Presence of arsenic in the coastal areas is low because most of the groundwater in this saline area is extracted from arsenic-free deep aquifer. Detailed investigation in the Chittagong Hill Tracts area is yet to be done.



Map-1.1: Average concentration of arsenic in tubewells from each of the administrative divisions. Note that the Chittagong division includes the area east of Dhaka as well as the narrow strip of land sampled along the SE coast of Bangladesh., No tibewells were sampled in the Chittagong Hill Tracts

Source : BGS and DPHE, 2000.

Widespread arsenic contamination of shallow aquifers in Bangladesh is a major problem in the water supply sector since it is the primary source of drinking and cooking water. Hundreds of millions of people have been exposed to arsenic contamination through drinking water in various areas of Bangladesh including this study area. It is indeed a matter of great concern that environmental impact of arsenic has been causing widespread disquiet in Ramganj, Lakshmipur, as well. Arsenic concentration in groundwater has been increasing in here.

In the recent years arsenic contamination of groundwater has became catastrophic in Bangladesh. Which is different from other calamities such as cyclones floods, drought, SARS virus. Once upon a time these calamities would be the last touch. But arsenic doesn't completely feckless easily. It has caused enormous health hazards and social problems. Tubewell which became unavoidable for supply of safe drinking water in rural Bangladesh and abroad is now a branded monster.

Arsenic pollution is an anxiety for our country. In chemistry arsenic is referred to as a violently poisonous white substance of brittle element. Now this element is detected to be present in large quantity in the tubewell water of many districts of Bangladesh. It causes a kind of health hazard. Press reports on this matter are drawing attention of all classes of people to be aware of it. The people should also take all possible measures to prevent themselves from arsenicosis. Drinking of water polluted by arsenic causes diseases like sores and stomach troubles. So it is urgently needed to teach the people how to get rid of arsenicosis. At present, an antidote is discovered to purify water polluted by arsenic. Besides, the World Bank has agreed to

extend all possible help to mitigate the arsenic problem in our country. So our government is also trying hard to train her people in this regard.

From available data it is clear that unacceptable levels of arsenic in groundwater have been found in vast majority of the districts of the country as well as out of country and a large number of patients are suffering from arsenicosis and its complications. Poisoning by arsenic is slow process. It damages the kidneys, the liver, the skin and the nervous system. it is due to a gradual build-up of the poison in the human body. Eventually people start to show symptoms and become unwell. Deaths due to long-term poisoning make it even more important to address the problem as soon as possible. This is in effect a race against time to safe water for everyone. Many people currently drinking arsenic contaminated ground water may develop problems soon. they must attempt to find safe source of water. Thousands of people in Bangladesh are suffering from arsenicosis and more are being affected everyday. Arsenicosis is caused by drinking tube well water containing arsenic. People who drink uncontaminated water do not catch arsenicosis from affected people.

The majority of the tubewells in Bangladesh are free from arsenic, but they need to be tested to separate the safe from the unsafe and, in many areas, this has not yet been done. Tube wells, which have been tested for arsenic, should be painted green if they are safe or red if they are unsafe. Deep tubewells are free from arsenic and bacteria although they will need testing in the future to ensure that it is still the case. Surface water in ponds and rivers is a potential source of arsenic-free water. However, most surface water in Bangladesh is heavily polluted with dangerous bacteria. No surface water should be used without some form of treatment. Drinking water is

unsafe for human use when the arsenic exceeds 0.01 microgram per litre of water. This is the international standard set by World Health Organisation. But Bangladesh standard is 0.05 microgram per litter of water. In Bangladesh there are about 4 million tubewells providing safe water to 95 per cent of the whole population. It is understood that the result of a widespread arsenic contamination of ground water will be a Titan catastrophic.

1.2. Objectives of the Present Study :

The presence of arsenic in groundwater at Ramganj in Lakshmipur is the most serious health hazard. The arsenic concentration of this area is greater than 0.05 mg/l signifying that thousands of people are as badly risk of arsenic poisoning.

In the above perspective the broad objectives of the present study are as follows :

Spatial dimension of groundwater arsenic problem, arsenicosis situation and health seeking behaviour of Arsenicosis patient in the Ramgonj area.

The specific objectives are:

i) to find out the cause of groundwater Arsenic Contamination in the study area,

ii) to observe the seasonal variation of groundwater Arsenic problem

ii) to determine the relationship of Arsenic with different parameters,

iii) to determine the level of groundwater Arsenic Concentration in the study area by "Field Kit" and Laboratory test,

iv) to know vertical position of Arsenic concentration in the borehole data in Avirampur study point,

v) to compare the Arsenic concentration data with other hydrogeo-chemical data (both water and soil),

vi) to investigate the socio-economic and demographic condition of the arsenicosis patients.

vii) to examine the physical, environmental and psychological situation of victim of arsenicosis patients.

1.3. Logical View of the Research:

Arsenic contamination of groundwater is a great threat for Bangladesh. Practically there is no specific treatment of arsenicosis patient. Restriction of arsenic contaminated drinking water can reduces the health hazard. So, to comb at the arsenic toxicity in our country via drinking of tubewells water. More emphasis should be given on arsenic free water. We have to find out the underground arsenic contaminated layer and tubewells should be installed in the arsenic free specific layer. Although it is very small baseline study it will explore new information to the researchers for furthers research in this field.

The arsenic problem is became a global problem which has hit the Bangladesh severely. Groundwater extraction has steadily increase since1970s, together with the intense period of draught in recent years, have resulted continued fall of water levels in different subzones, with the environmental consequence. Arsenic has become widely known that there is a problem of arsenic in tubewell water in many parts of Bangladesh.

At present, various agencies in the health sector such as Dhaka community Hospital (DCH), International Center for Diarrhoea Disease Research, Bangladesh (ICCDDR,B) and water sector such as National Institute of Preventive and Social Medicine (NIPSOM), Division of Public Health and Engineering (DPHE), Bangladesh Water Development Board (BWDB) have been working on Arsenic related activities with the assistance from international donor agencies and NGOs. Universities have began exchange the views on arsenic related study at the present time. Field surveys on arsenic concentration and water quality measurements had already started using various methods by different organisations. These results are scattered and very few exchange of study findings is obsefved. It is very necessary to have the results coordinated and shared with other organisation. In this connection. Bangladesh Government in one of its recent movements set a National Arsenic Mitigation Information Center (NAMIC). This is a part of the world Bank financed Arsenic Mitigation Project, which will deal to collect, manage, interpret and disseminate all relevant hydro-gedogical, water quality, health socio-economic and technical information. Besides the most of the works of government and non-government has found in the head of health seeking behaviour. For a proper cause and effect of groundwater arsenic problem in Bangladesh, we need to know the present situation of related studies. However, the present study will try to examine the mobilization of arsenic in groundwater aquifer with other chemical parameters.

Though many countries of the world and South-east Asia, like India, Taiwan etc. have reported the toxic effect on human health due to presence of high level of arsenic in their tubewells water, but no extensive study has been

done in our country about the contaminated tubewells including deep drilling and the extent of contaminated level. A geo-environmental and demographic survey among the users of the contaminated tubewells in the affected areas where presence of high concentration of arsenic in tubewells water will give us valuable information about the subsoil water level which is free from arsenic contamination, so that during the installation of tubewell this may be utilized by the respective authority for drawing underground water from that specific level which is free from arsenic.

1.4. Limitation of the research:

The limitation of the research in Geo-environmental analysis in Bangladesh are manifold. Environmental research is too tough and peril research. It is related to nature and laboratory. So, laboratory research is very costly. Besides it has no sufficient information and data. Extension field visit, drilling soil, collect of accurate and precise groundwater an other problem of this studies. The facilities that students of sophisticated environmental research enjoy in many countries today interim of laboratory analysis, data processing and computing facilities are also negligible. Even more frustrating is the lack of relevant literature, both in terms of books or research monographs and journals of relevance.

Every research has social case, for this social case involving long questionnaire schedule interviewing. It is the increasing lack of trust and co-operation from the respondents. It also a great problem. The educated elite pose tougher problems, particularly in areas which are also being frequently presented by environmental, social researchers, both private and governmental. To add further to the problem, the material to be sampled is usually very non-homogeneous. The analytical chemist who specializes in

the analysis of environmental samples is choosing to work on some of the most challenging problems in analysis. Because and analysis are often present in extremely low quantities and matrix can be very complex.

CHAPTER TWO

2. ENVIRONMENT AND ARSENIC SITUATION

2.1. Introduction:

Environmentalism is a fairly new movement in the world. It is getting top priority in national policies among the developing countries. During perfect planning due consideration is given to social, cultural and environmental impacts. As our planet becomes more crowded and industrialization becomes more widespread, the deleterious effects on the environment have become obvious. The entire world is the environmental scientist's laboratory. Environmental science takes for its own the study of the composition of water, soil, atmosphere and how materials are taken up and given off by plants and animals. Deterioration of the environmental reached the significant levels with the dramatic increase in human population, accompanied by industrialization, which took place over the past century or so. Major problems brought about by these changes are the contamined of water, soil, air, growth in the amount of hazardous waste, depletion of arable land, energy, and other natural resources, increased exposure to toxic chemicals in food, water, soil and air; and exposure to radiation. It was not until the 1960s that an awareness of these problems grew all over the world. Since then, a plethora of environmental regulations have been promulgated to protect our environment. All environmental studies ultimately depend on the results of chemical analysis of samples of water, soil and biological organisms.

2.2. Man and Environment Interrelationship:

Environment means the inter-relationship existing between water, air, soil and physical property and their relationship with human beings, other

animals, plants and micro-organisms. The environment is the treasure which supports life, WECD known as Brundtband commission defined Environment as "where we all live". It has been suggested that the Holy Quran draws human attention to practically everything in nature. Man's endeavor to satisfy his growing demand to improve his living initiated the modification of the natural system through technological innovations. Now man has invaded nature and introduced modified resources in the environment combining technology with natural physio-chemical and biological system known as development resources.

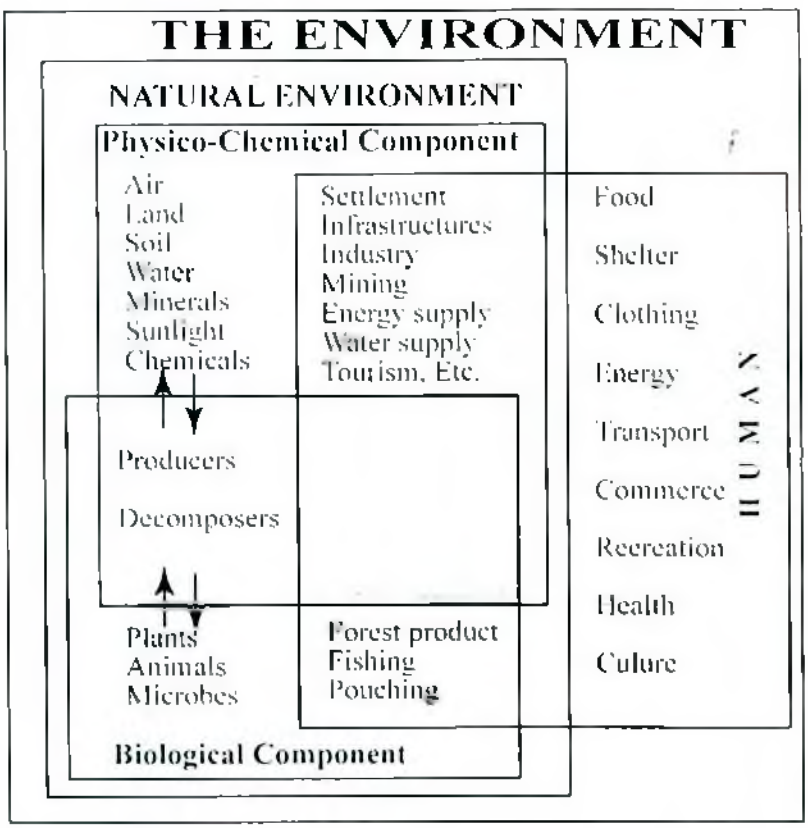


Figure-2.1: Natural-human Interaction in the Environment

Source : Ahmed, 2002

Hossain in his study, "Man/population and Environment Interrelationship" explain the various factors of population and environment which are related

with each other. A figure is given below namely "population and environment Interrelationship" according to Hossain's study.

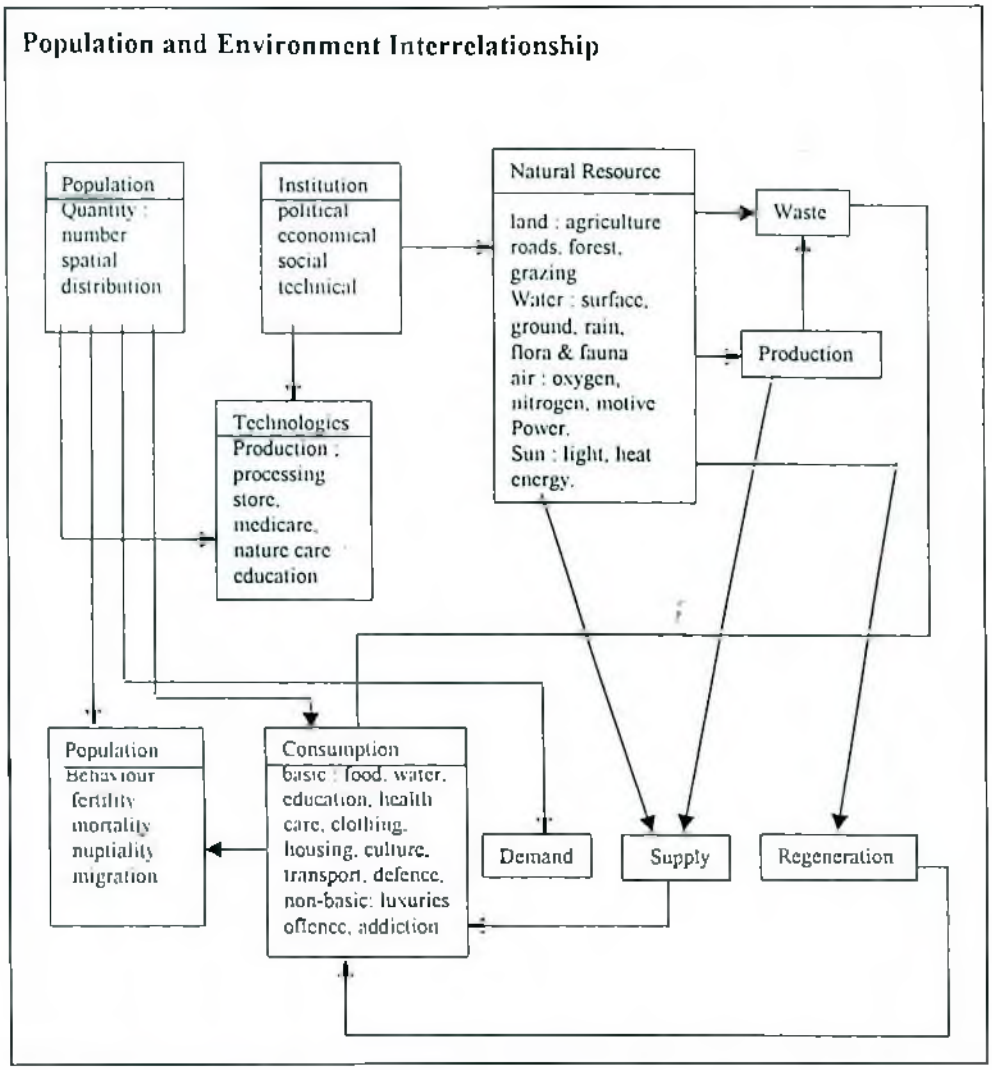


Figure-2.2: Population and Environment Interrelationship

2.3. Environmental Conditions and Arsenic Contamination:

Each person has a fundamental and inalienable right to a healthful environment. For many year people were mainly interested in how the environment influences people rather than how people affect the environment. It is only recently, that the converse seems to be true that how human actions affect the natural environment.

Contamination of the environment is one of the most horrible ecological crisis to which we are subjected today. We know that three basic amenities for living organisation are air, land or soil and water. Sometimes in the past, these amenities were pure, virgin, undisturbed, uncontaminated and basically more hospitable for living organisms. But the situation is just reverse today, because of increased human activity following the progress in science and technology in present day scenario, leading to pollution of environment and serious ecological imbalance which in long run, may prove disastrous for country.

Bangladesh being located downstream of the mighty rivers, the Ganges and the Brahmaputra, works as a retention basin of excess water carried by the river and vice-versa is dependent on soil-water interaction in the subsoil environment. The mechanisms of arsenic release in groundwater and health effects of chronic ingestion of arsenic water drinking water are not well understood. The magnitude of the problem is yet to be ascertained. A better understanding of the possible causes and extent of arsenic contamination, population exposed to high level of arsenic and possible health effects is essential to mitigate the problem.

2.4. World Situation of Arsenic :

Water has existed on earth as early as 3000 millions years ago. It is the commonest fluid in nature. Water, the synonym of life. Water effects the life of every human on Earth and can be detrimental to our livelihood; the quality affects our health and well being.

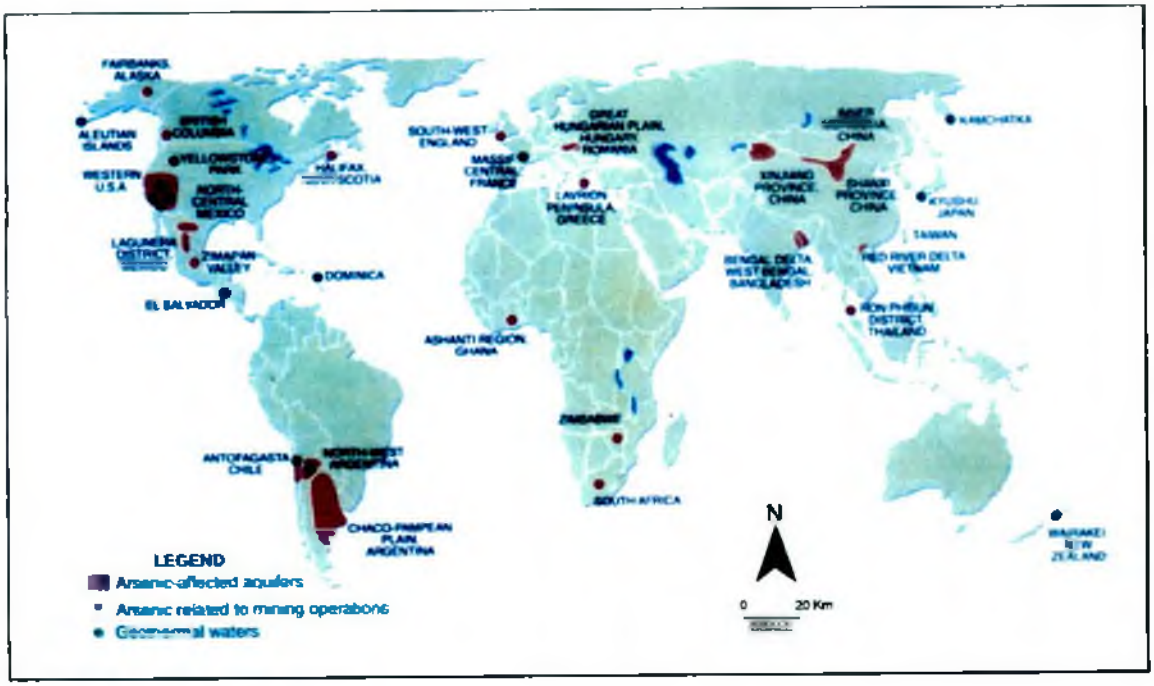
Water plays a vital role by conserving lives and their healthy environment. If water is contaminated, it may be dangerous for plants, animals and human being. Water contamination is a severe problem in domestic and industrial

purposes and water for human consumption must be free from hazardous chemical substances. Groundwater was treated as the best sources of safe drinking water, before arsenic contamination was reported. Arsenic is a poison in all its forms. It is also a poison omnipresent inside the earth. Arsenic is the king of poisons and has plagued human beings since the days of antiquity.

Traces of arsenic are almost universal. Arsenic is often viewed as being synonymous with "toxic". The naturally occurring toxicant, arsenic, causes serious health hazards as reported in many countries of the world. Humans unavoidably exposed to the arsenic compounds present in drinking and cooking water. a positive correlation was found between excessive intake of arsenic via drinking water and arsenicosis. Presence of arsenic in surface water and groundwater resources of many countries in the world has been reported because of dissolution from earth crust (Mosaferi et al., 2003). Arsenic is a naturally occurring element that ranks twentieth in abundance in the earth's crust, four-tenth in the seawater, and twelfth in the human body with an average concentration of arsenic in earth of 1.5 - 2 mg/kg in relation to other elements (NAS, 1977).

Arsenic is the king of poisons and has plagued human being since the days of antiquity. Arsenic is both a causes of large scale environmental contamination and a serious health hazard. Many incidents of arsenic contamination in the environment and cases of victims are reported from various countries of the world. Causes of arsenic contamination of water sources also been found in India, Chile, Mexico, Argentina, Hungry, United Kingdom and the United States (Map-2.1).

Arsenic contamination of ground water is now a major environmental pestilence and international problem of the world. Highly elevated ground water concentrations of arsenic are common in many areas of the world, causing life-long exposure for a large number of people (Vahter, 1998). Many people at different corners of the world are afraid of this hazardous health problem. Some of them are already affected and the rest of them are at risk. The world situation of groundwater arsenic seems to be long and many of the arsenic affected areas are located in arid region. Except Bangladesh and India, arsenic contamination of drinking water source both surface and groundwater has been reported in a number of Asian countries including China, Mongolia, Taiwan and Thailand.



Map – 2.1: World Situation of Arsenic
Source: Chowdhury, 2001

In China : In China, chronic endemic arsenism was first found in Jizyi and Tainan, Taiwn province in 1968 (Sun et al., 1998). The region of high

arsenic concentration is in the Tumot and Hetao plains, situated to the south of the Yin Shan mountains and to the north of the Yellow river. The areas of the region with high arsenic is 10000 km^2. In addition, there is high arsenic spring water in the valley to the east of Daxing AnLing. Its length is 50 km^2. The Tumot and Hetao plain on the south of Da Qing mountain and Lany mountair. It is old metamorphic rock. The arsenic content is high. It is distributed in the fore-fan alluvial lake accumulated low-lying area. It is bounded by the Yellow River and Black River. High arsenic water is mainly distributed in low-lying area. High arsenic region is situated in five regions, ten countries, 52 townships and 575 villages, 1774 people were diagonised the Chronic arsenism and the population involved reached 600 thousand (Sun et al., 1998), a large scale survived in 1989.

The disease on the continent of China has been reported only in recent years. Although its history is short, the situation and the spread of the disease are very serious. In the mainland the disease was first found in kuitun, Xinjian province in 1980. There were more than 2000 patients out of population of about 100,000 (Wang et al., 1983). The number of patients with "Black foot" disease amounted to 1636 by the end of 1985 in Jiayi and Tainan, Taiwan provinces (Zheng et al., 1995).

Chronic arsenic poisoning in China can be divided into types according to the exposure sources. One is caused by drinking water, in which the arsenic concentration is very high. Xinjiang, Inner Mongolia, Shanxi and Taiwan belong to the drinking water type. Most of the people drink water from a pump well more than 20 m deep and the arsenic concentration ranges from 0.15 to 2.0 mg/l according to different areas, the highest being up to 4.4 mg/l which was 88 times the 0.05mg/l China standard. The second is caused by

coal burning. People use coal containing high levels of arsenic as fuel for cooking and drying grain in the kitchen and so inhale high levels of arsenic concentration in the air. In Guizhov the arsenic content in coal was up to 9600 mg/kg and arsenic in kitchen air was 0.003 – 0.11 mg/m^3. The third type is caused by industry exposure, mainly copper smelting and arsenic mining. There are about 30,000 workers in the industry exposed to arsenic. Besides the skin changes in all three types of arsenic poisoning. Lung cancer incidence was high in coal burning and industrial exposure, especially in arsenic mines. Another characteristic of endemic arsenism in China is that the fluoride content was also high in both drinking water and burned coal with high arsenic concentration. The "Fluoride and Arsenic Society of China (FASC)" was established in 1996 and is now organizing research into the field of fluoride and arsenic throughout the country (Sun et al., 1998). In the 140s – 1950s, high arsenic large mouth water-wells were sunk in the western part of Huhhot basin. Lung and other cancer emerged in the 1970s.

In Japan : At the Teroku mine and refinery in Miyazaki, Japan, white arsenic was intermit-tently produced by calcinating arsenoprite for about 28 years between 1920 and 1962 (Yokoi, 2001). In early 1930 five members of a family died and few members were sick in every house. One of the survey revealed that the average life span become shorter during the time of the mine operation. This was said to be due to arsenic toxicity. In July 1996, the Japanese Environmental Agency said "epithelium carcinoma on the urinary tract including the bladder" to the caritoxia for compensation for chronic arsenic poisoning. Till then, the Agency had admitted only skin, lung and liver cancers as caused by arsenic. There have been several reports on industry related exposure to arsenic through metal smelting in Toroku and

Matsuo and through drinking water contamination from factory waste in Nakajo Japan.

In Taiwan : Since Chronic endemic arsenism was found in Taiwan in 1968, the diseases has been reported in recent years (Sun et al., 1998). Although its history is short, the situation and spread of the disease are very serious. The Environmental Protection Agency (EPA) is under congressional mandate to revise its current standards for arsenic drinking water (Morales et al., 1998). A cross-sectional study included 37 villages in a region of Taiwan where high concentrations of arsenic in wells had been observed. Subjects were examined for skin lesions and skin cancer. Concerns arise when an ecological study design has been used. This means that subjects are not individually assessed for exposure, but instead are assigned an exposure based on the group to which they belong, resulting in the statistical of measurement error. A total of 349 residents living in arseniasis-hyperendemic villages of southwest Taiwan were recruited in 1996. Cumulative arsenic exposure was derived from history of consuming artesian well water and arsenic level in the well water.

An association between ingested inorganic arsenic through water consumption and risks of various health effects has been reported among residents in blackfool disease endemic area on the southwestern coast of Taiwan. A large cohort of 8102 residents in a newly identified arseniasis endemic area on the northeastern east of Taiwan. Study subjects were followed up to obtain occurrence of various disease. Wide survey for arsenic confirmation in 83656 well in 314 township in Taiwan showed that wells containing high arsenic water clustered in the southwest cost and leaning basin and has significant association between arsenic level in well water and development of various types of cancer.

In Iran : Kurdistan province is in west of Islamic Republic of Iran between $34^0 44'$ to $36^0 30'$ north, and $45^0 31'$ to $48^0 16'$ East and is in neighborhood to Iraq. In Iran like many other countries, geogenic arsenic could affect ground water resources in some area with Kurdistan province. Kurdistan, a western province of Iran, is facing this problem and arsenic is endemically present in drinking water of rural areas of this province. There is exposure to arsenic in some villages of this area for more than 30 years. As a result, chronic poisoning manifestations such as skin lesions Keratosis, pigmentation and even amputation due to gangrene are reported in these villages. Measurements have shown arsenic levels in some water resources as high as 1.48 mg/l. The WHO provisional guideline value for arsenic in drinking water is 10 µg/l (WHO 1993). However, in Iran, like as many other countries and indeed in all affected developing countries this values is 50 µg/l (ISIR, 1996). According to available reports, in Iran several areas have been affected by natural arsenic contamination. Although government took many initiatives to supply fresh water to villages, as it is not routine to measure the level of arsenic in drinking water. Some of these water supplies are polluted and some people are exposed to arsenic. exploration of polluted water supplies throughout the country is one of the priorities of government and is being conducted now (Mosaferi et al, 2003).

In Thailand : Several thousand people of Ronpibool district, Nakorn Srithammaral province have been exposed to arsenic through the contamination in surface groundwater for more than seven decades. After the first case of chronic arsenic poisoning was detected in 1987 (Choprapawon, 1998). The source of arsenic contamination in ground water at Ron Phibun is not fully understood. Primary tin deposit and associated

high concentrations of arsenic occur at this mountain site. There is also arsenic in alluvial sediment and in waste from mineral dressing of tin ores. All three types of materials may be major sources of arsenic in the Ron Phibun area. The mineral processing of the ores may have generated significant amounts of oxidized arsenic. This waste may be a significant source of soluble arsenic in ground water. In early 1998, the principal investigator conducted four focus group discussions in Ron pibool/ Ronphibun District, Nakorn Sri Thammarat, the southern province of Thailand. The results from the focus group discussions showed that the toxicity from arsenic contamination in natural water sources in Ronpibool District had been recognized by the Thai government and the residents of this district for more than 10 years. Since 1987, the government sectors have launched several interventions. Major measures include: providing of alternative water sources (e.g. distribution of big water jars to collect rain water, construction of deep tube wells and construction of village pipe water system). Periodic monitoring of drinking water and environmental samples, case detection and supportive treatment for patients with severe skin manifestations. Also included were health education for the villagers; and site remediation to clean up the 3,000 tons of high-grade mine waste piles. However, the major interventions during these ten years show less success than expected. All four group discussions agreed that they still lack a good understanding of the situation and desire continuous communication with the government sectors. Villagers are concerned about their economic status and some old life styles inhibit their participant in solving this problem. The investigators conducted a survey of all households (approximately total 5,000 households) in the district. Information was collected on demographics, sources of water used and suspected cases of skin lesions.

After the survey was completed, household mapping was done in a manner that the villagers could easily utilize for long term follow up and design the appropriate interventions for the specific problem of each village. It is proposed that a well-planned, long-term study should be established in order to control the problem and to provide a rich source of scientific knowledge to help us understand the specific disease occurrence and changing pattern of illnesses in this area.

In Thailand, environmental arsenic exposure has received attention since 1987 because of skin manifestations of "Black Fever" resulting from ingestion of water containing arsenic. Most of the inhabitants of Ronpibool sub-district prefer the daily drinking and use of well water which has been contaminated with arsenic for a long time. They have habitually ingested this well water for drinking and cooking because it is sweet, delicious and full. Chronic arsenic poisoning will increase in severity day after day unless inhabitants stop ingesting well water and drinking water supply is made safe for them. Neither the routine monitoring of arsenic contamination of well-water nor the monitoring of public drinking water for safely is presently mandated in Ronpiboon sub-district. The population living in this area is still at risk of gradual chronic arsenic exposure (Siripitayakunkit et al., 1998).

During the years 1987 and 1988, chronic arsenic poising turned into a hot political issue producing lots of confusion in many sectors; including the public, the media, government officers, NGOs etc. A lot of information, either correct or incorrect, was disseminated through the mass media and caused economic difficulty to the Ronpibool villagers the long term effects of which are still evident now. The government has implemented several interventions, which includes public education, providing tanks for storage

of safe drinking water construction of new small water supply facilities, monitoring of arsenic level in surface groundwater and other environmental media, and treatment of affected individuals etc; none of these government interventions have solved the problem (Choprapawon, 1998).

A novel soil gas technique was applied to detect and determine the subsurface arsenic contamination at Ron phibon/Ronpibool, Nakon sitamarat province of Southern Thailand. This technique was tested for the first time in this type of geo-chemical environment in order to detect volatile forms of arsenic.

In India : Arsenic contamination of groundwater is west Bengal, India has become not only a serious national problem but also a serious epidemiological problem. It demands a concerted effort on the part of all concerned governments. Scientific community, health personnel, public health departments, science organizations and the victims to face and overcome the consequences of arsenic pollution as well as to arrest of far as practicable the spread of this pollution. Arsenic in ground water above permissible limit (0.05 mg/l) has been detected in eight districts of west Bengal viz. Malda, Murshidabad, Nadia, Burdwan, North and South 24 Parganas, Howrah and Hoogly. This eight districts are more arsenic affected area of west Bengal in India. The area of this region is 38,000 sq. km. having about 38 million population. In West Bengal more than 1.5 million people are drinking arsenic contaminated water (Das et al., 1998). At present 61 blocks by the side of the river Ganga and adjoining areas are affected by arsenic contamination in groundwater are all located in upper delta plain and are mostly in the abandoned meander belt. Actually, the arsenic affected area is so vast that it needs some years to know the actual magnitude of this

calamity. The first report of chronic arsenic toxcity was made by Garai et al in 1984 and Saha 1984. Subsequently several reports appeared in Indian and International literature (Chakraborty and Saha 1987). Chronic toxicity from drinking water containing high level of arsenic has been reported in 1983 from various institutes of west Bengal. A small incidence of similar problems was revealed from Chandigarh and Punjab both 1976 and 1979 was characterized by the involvement of several system of serious health hazards (Talukder, 1997).

In Hungary : Before 1984 the arsenic content of piped water in Karcag a town on the great plain of Hungary with 24,000 inhabitants, was between 0.095 and 0.130 mg/l, i.e. well over the hygienic limit value of 50 µg/l. Due to various interventions the arsenic content started to decrease from 1984 but a steady concentration below 50 µg/l could be reached only from 1990 on. Drinking water contamination by arsenic depending upon the geographical position and depth of water giving layers which is twice or thrice of the maximum permissible limit of 0.01 mg/l in the country (Talukder, 1997). The adverse effects drinking water related arsenic exposure some demographic data for the years 1975-95 of Karcag were compared to those of Torakszentmiklos, a town with a similar number of inhabitants and to the average values of country Jasz-Nagykun-Szolnok. Before 1984 the frequency of spontaneous abortion, stillbirth, preterm birth, perinatal and infant mortality were all significantly higher in Karcag for the high level of arsenic in the drinking water than in the reference populations. From 1984 on, all above mentioned frequencies started to decrease and the difference between the data of Karcog and whole country, especially in the case of stillbirth and perinatal mortality were lower than those in the central town, although still slightly higher than the country's values.

In England: Southwest England is a arsenic affected area. Deven and Cornwall are small area but a high level arsenic contaminated area in southwest England. Exposure was defined as residence in area where stream sediment concentrations of arsenic were ≥ 100 μg/l, estimated at the level of electoral enumeration district. Within the limitations of the geographical (small area) approach, no significant association between arsenic contamination in former mining areas and risk of bladder cancer was found.

In Germany: As early as 1879 it was suggested that high rates of lung cancer in Germany miners may have caused by inhaled arsenic. A few years later Hutchinson reported skin cancer in patients who had taken arsenical medication.

Table-2.1: Worldwide Occurrences of Arsenic Contamination in Water

Location	Potential exposed population	Concentration (µg/L)	Environmental conditions	Source
Argentina	2,000,000	1-2,900	Natural; volcanic rocks and thermal springs	Groundwater
Bangladesh	>29, 000,000	1-4,730	Natural, alluvia	Groundwater
Bolivia	50,000	-	Natural and anthropogenic	Surface water and groundwater
Chile	500,000	100-1,000	Natural and anthropogenic; basin lakes, thermal springs, mining	Surface water
China	>500	40-750	Natural, alluvial sediments	Groundwater
Greece	150,000	-	Natural and anthropogenic; thermal springs and mining	Surface water
Hungary, Rumania	400,000	2-176	Natural; alluvial sediments; organics	Surface water
Inner Mongolia	>100,000	1-2,400	Natural; alluvial and lake sediments; high alkalinity	Groundwater
Mexico	400,000	8-620	Natural and anthropogenic; volcanic sediments, mining	Surface water and groundwater
Nepal	-	-	Natural, alluvia	Groundwater
Spain	>50,000	1-100	Natural, alluvial sediments	Surface water
Taiwan	>100,000	1-1,820	Natural	Groundwater
Thailand	15,000	1-5,000	Anthropogenic, mining	Surface water
Vietnam	>1,000,000	1-3,050	Natural, alluvia	Groundwater
West Bengal, India	>1,000,000	10-3,880	Natural, alluvia	Groundwater

Source: Rahman, 2002

In Russia: Transbaikalian in Russia has bio-geo-chemical zones where arsenic is above the manpower permissible limit in soil and water has shown the higher mortality and morbidity rates high incidence of cardiovascular gestro-enterologic and oncologic disease.

In United States: Arsenic is a naturally occurring element in rocks. Soils and the waters in contact with them. Recognized as a toxic element for centuries,

arsenic today also is a human health concern because it can contribute to skin, bladder and other cancers (National Research Council, 1999). Recently the NRC (1999) recommended lowering the current MCL allowed for arsenic in drinking water of 50 µg/l (Micrograms per litre), citing risks for developing bladder and other cancers, the USEPA will propose a new and likely lower, arsenic MCL during 2000 (USEPA, 2000). High arsenic concentrations in ground water have been documented in many areas of the United States. Within the last decade, parts of Maine, Michigan, Minnesota, South Dakota, Oklahoma and Wisconsin have been found to have widespread arsenic concentrations exceeding 10 µg/l. These high concentrations most commonly result from: (1) Upflow of geothermal water, (2) dissolution of or desorption from, iron oxide, and (3) dissolution of sulfide minerals. Because the MCL for arsenic is currently being evaluated, estimating the exceedance frequency for different arsenic concentrations in regulated water supplies is particularly timely. Estimates of the frequency of exceedance, which are based on analyses of about 17,000 ground water samples, suggests that about 40 per cent of both large and small regulated water supplies have arsenic concentration greater than 1 µg/l. The frequency of exceedence decreases for greater arsenic concentrations – about five percent of systems estimated to arsenic concentration greater than 20 µg/l (Welch et al., 1998). Arsenic concentrations in ground water generally are highest in the west. Parts of the Midwest and Northeast also have arsenic concentrations that exceed 10 µg/l, the WHO's provisional guideline for arsenic in drinking water. Arsenic concentrations appear to be lower in the Southeast, based on a smaller amount of data. Concentrations of naturally occurring arsenic in ground water vary regionally due to a combination of

climate and geology. At a broad regional scale, arsenic concentrations exceeding 10 µg/l appear to be more frequently observed in the western U.S. than in the east (Welch et al., 2000). The current drinking water standard for arsenic in the United States is 50 ppb and a more stringent standard in the range of 20 to 2 ppb is being evaluated by the USEPA. At the present time, only a few smaller communities in the U.S., such as Hanford, California and Fallon, Nevada, use source waters with arsenic concentration at the level of the current MCL. Some larger communities, including Los Angeles, California and Albuquer que, New Mexico, use source waters that exceed the world Health Organization provisional guideline value for arsenic of 10 ppb (Hering, 1998) that aforesaid. A notable exception is the Yellowstone geothermal system, which causes arsenic concentrations as high as 360 µg/l in the Madison River at the park boundary, and as high as 19 µg/l arsenic in the Missouri River at a point 470 km downstream.

In Mexico: The Mexico is an arsenic affected country in Mid America. Lagunera is the most arsenic contaminated region in the central part of north Mexico. Ampueros, Coahuila, a town which had an average of 0.415 mg/l arsenic in its drinking water. Nazareno, Durango, whose average concentration was 0.025 mg/l. In both rural towns, most arsenic was in its inorganic form and more than 92 per cent was in its pentavalent state (Razo et al., 1998). Ampueros, Coahuila are high exposure town and Nazareno, Durango are low exposure town. The concentration of arsenic in the drinking water of the exposed town (Ampueros) was about 40 time higher than the provisional WHO drinking water guideline of 10 µg/l arsenic (WHO, 1993), whereas that of the low exposure town (Nazareno) was about

2.5 times higher. Although little information is available on the concentration of as in urine from exposed children, the average values of as species and TAS in children from Region Lagunera here reported are among the highest reported in the literature. In fact, average TAS concentration in children's urine was higher than adults exposed to similar As concentrations in drinking water in the same contaminated area (Razo et al., 1998).

In Chile: The presence of arsenic in some drinking water supplies in the North of Chile has a natural origin due to the hydrogeologic characteristics of the area, which has a predominance of quaternary volcanism (Sancha, 1998). Since rivers which originate in the Andes springs have developed their hydrographic basins in volcanic materials (Henriquez, 1968; Henriquez, 1978). Arsenic occurs, principally, as an inorganic form with predominance of the pentavalent specie (Sancha et al., 1992). The arsenic contaminated water presents in general, a low level of turbidity and natural organic materials and high level of alkalinity, chloride, hardness, Sulfate, boron fluoride and silica (Sancha, 1998). Before water treatment utilities for arsenic removal were set up in chile, skin lesions were detected especially in children also some serious cardiovascular cases were reported (Zaldivar, 1974). The health effects reported during the sixties forced the Chilean authorities to worry about problem and search for a solution with the participation, in the first stage of German researchers. Thus in the seventies the first two utilities for arsenic removal were built in Chile. Later on, in the eighties, based on studies carried out by Chilean researchers, two new utilities were built and two existing ones were improved to produce water with a maximum arsenic level in the range of 0.040 – 0.050 μg/l.

Table-2.2: Area, source of arsenic exposure and population of emerging epidemics of arseniasis in Asia.

Area		Source	Population	Reference
Bangladesh		Well-water	50,000,000	Dhar et al. (1997)
China				
	Guizhou	Coal burning	200,000	Cao (1996)
	Inner Mongolia	Well-water	600,000	Cao (1996)
	Shaanxi	Well-water	1,000,000	Cao (1996)
	Xinjiang	Well-water	100,000	Cao (1996)
	Yunnan	Metal smelting	100,000	Niu (1996)
India				
	West Bental	Well-water	1,000,000	Chowdhury et al. (1997)
Japan				
	Toroku Matsuo	Metal smelting	217 patients	Hotta (1989)
	Nakajo	Contaminated water	44 patients	Tsuda et al (1989)
Philippines				
	Mindanoa	Geothermal drilling	7	Hironaka (1995)
Taiwan				
	Southwest coast	Well-water	100,000	Tseng (1968)
	Northeast coast	Well-water	100,000	Chiou et al. (1997)
Thailand				Choprapawon and
	Ronpibool	Mining	1,000 patients	Rodcline (1997)

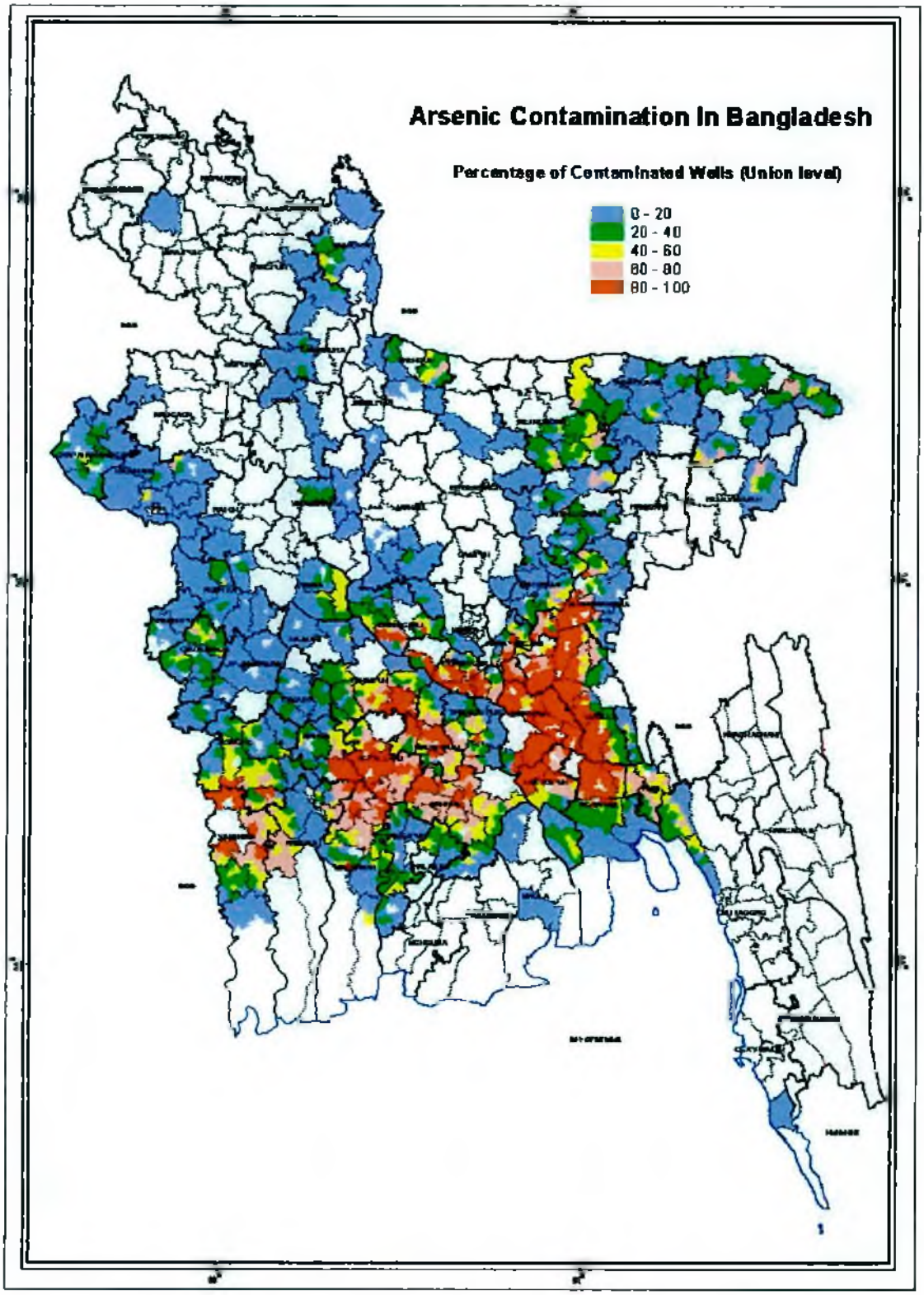
Source: Chen, et al., 1998, p.115

Bangladesh, China and India have reported significant contamination of their groundwater resources by arsenic. Arsenic contamination is also detected in Cambodia, Myanmar, Pakistan, Vietnam and Afghanistan. These fluoride. Lao PDR and Cambodia also expressed concern about the potential occurrence of arsenic. All these countries have expressed a need for support for water quality surveys.

2.5. Arsenic Situation in Bangladesh:

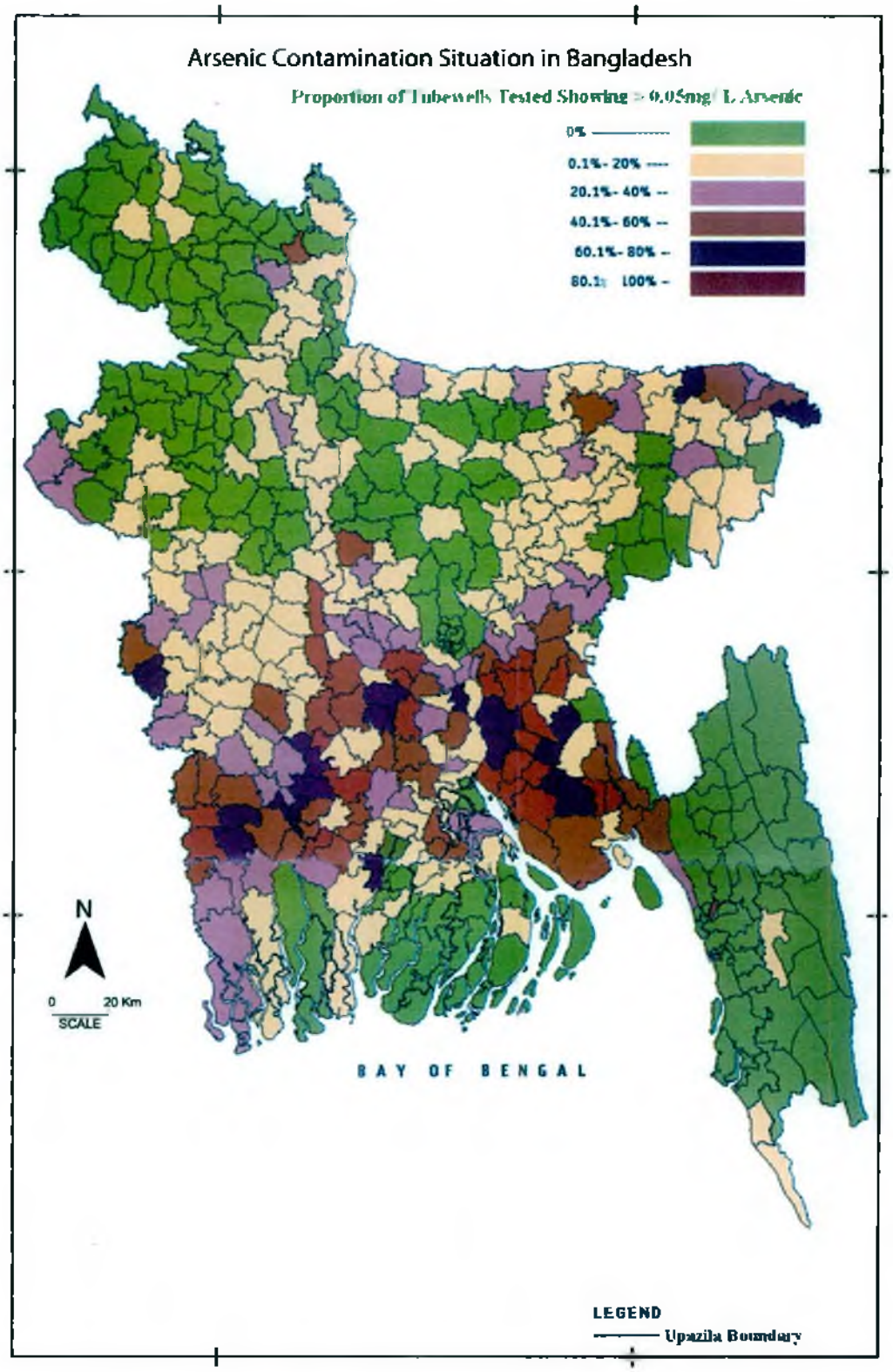
The People's Republic of Bangladesh stretches a territory in the northeastern part of the Indian subcontinent in South Asia the Bay of Bengal between $20^0 34' - 26^0 38'$ N latitude and $88^0 01' - 92^0 41'$ E longitude. The country forms the capstone of the Bay of Bengal of the Indian ocean which has great influence in the land and population. It has a territory of 1,47,570 sq. km and a population of near 130 million. It is a small and very densely populated and has an agrarian based economy and rural based human settlement. Geographically Bangladesh are the largest deltaic land of the world which is created by the three vigaur river systems i.e. the Ganges, the Brahmaputra and the Meghna. It is a tropical riverine country with 230 rivers, both large and small, size, crisscrossing the country. Major part of the country is low lying and covered with fluvial, fluvio-deltaic and coastal sediments. Because of its geographic location, a large part of the country is affected in each year by devastating floods.

Arsenic contamination of the groundwater of Bangladesh is a great concern of the present time. It is a recent environmental episode. The world's four major arsenic calamities are in Asia. The countries are Bangladesh, West Bengal, India, Inner Mongolia, Xinjing, P.R China and Taiwan. Arsenic contamination is the single biggest threat to Bangladesh's groundwater resources.



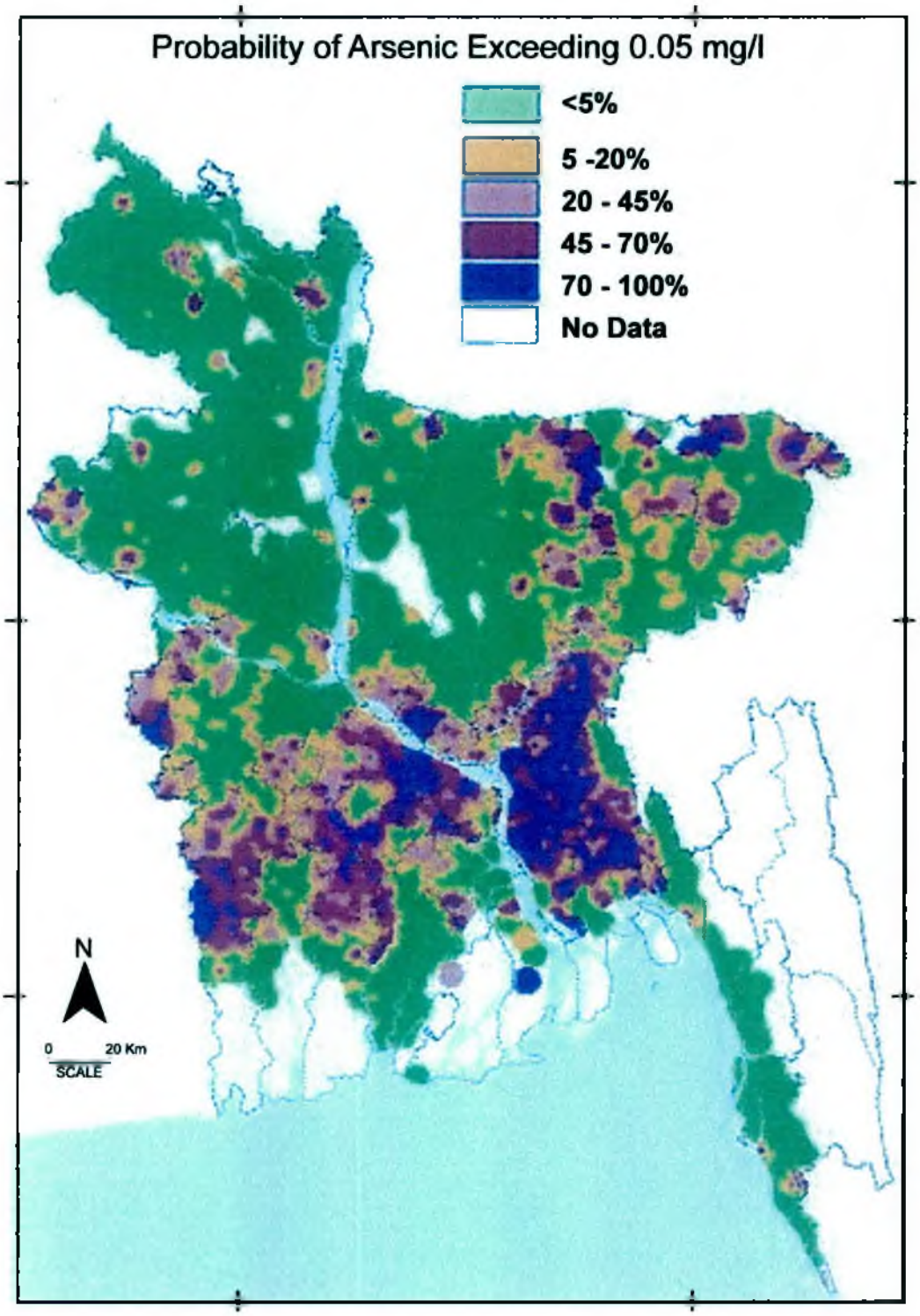
Map -2.2: Arsenic Contamination in Bangladesh

Source: BAMWSP, 2004



Map -2.3: Arsenic Contaminate Situation in Bangladesh

Source: BGS and DPHE, 2000



Map -2.4: Probability of Arsenic in Bangladesh

Source : http://www.bien.comiacic

The groundwater arsenic poisoning in Bangladesh appears to be directly related to the Farakka, Tista and other dams/barrages that India constructed in the Bangladesh and India's common rivers. The arsenic contamination in Bangladesh began after 1975 (Bridge and Husain, 2000).

It is so far reported that 61 out of 64 districts and 28 municipalities of Bangladesh are facing the menace of arsenic poisoning (Chowdhury, 2001). The four districts that have not yet been surveyed are Khagrachari, Rangamati and Bandarban. Arsenic in drinking water as a poison was first unveiled in the west Bengal of India in the late 70's (Acharya, et al., 1999). In Bangladesh, the Department of Public Health Engineering (DPHE) disclosed the occurrence of elevated arsenic in groundwater in 1993. Systematic survey throughout the country by DPHE and the British Geological Survey (BGS) in 1999 revealed that nearly 21 million people of about 47 districts of the country were drinking arsenic contaminated (As above 50 µg/l groundwater (Ahmed et al., 2002). The groundwater arsenic contamination in Bangladesh was first discovered by Chemistry Division of the Atomic Energy Center, Dhaka (AECD) at Village Barogharia of Chapai Nawabganj District under Rajshahi Division in late 1993 following reports of extensive contamination of water supplies by arsenic in the bordering areas of India (Ali and Tarofdar, 2002). The patients suffering from chronic arsenic toxicity was first diagnosed by screening hair and blood arsenic in 1995. It is generally known that arsenic problem is mainly geological and it is thought that the problem is being aggravated by anthropological activities (Alam, 2000). Ground water arsenic contamination and resulting arsenic toxicity were almost unknown in Bangladesh until early nineties, although in neighboring West Bengal, India these became evident in 1978. The earlier

discovery of arsenic in groundwater in West Bengal followed the diagnosis of arsenic poisoning in 1978. A large part of Bangladesh, covering the approximate area of 34 districts out of a total of 64 districts in bordering India (Ali and Tarafdar, 2002).

Borehole sediment analysis showed high concentration of arsenic in soil layers where it was found to be associated with Iron Pyrites. The Iron Pyrites were reported to be found in the soil layers of alluvial plain of Ganges of West Bengal, India and Bangladesh (Chowdhury, 2002).

Although scientists in Bangladesh and around the world are investigating the problem. But the exact cause of this contamination of ground water by arsenic is not clearly known. It was presumed by the geologists that in countries like Bangladesh, taping of ground water for drinking, irrigation and other household purposes causes lowering of ground water table which thereby invites oxygen to aerate it and triggers the oxidative processes. As a result, arsenic leaches out from the pyrites in soil. It dissolves in this water table and thus contaminates water.

Arsenic is present in trace amounts in the environment, particularly in soil and water. The reason(s) for mass contamination of subsoil water with arsenic in Bangladesh have not been well studied. However, various hypothesis has been put forward by different authorities to explain the situation. A group of geologists from Stockholm Royal Institute of Technology, Sweden hypothesized that arsenic is released from ferric hydroxide present as coatings in aquifer sediments under specific reducing conditions. Another explanation is that arsenic is derived from the oxidation of arsenic rich pyrite in the shallow aquifers because of lowering the water table due to over abstraction of ground water for irrigation. Some authorities

differ from this theory because of the conflicting observation that the "hot spots" in Bangladesh are not usually located where ground water withdrawal is very high. Findings of very low concentrations of sulfate in ground water are also contrary to the pyrite oxidation hypothesis.

A number of workers on the basis of field evidences in Bangladesh, now differ the pyrite oxidation theory. In an alternative proposal, the scientists try to explain that arsenic is basically transported and deposited in adsorbed from, onto the fine grained iron or manganese oxides i.e. iron oxy-hydroxides. As the pore water of the sediments, offer burial, becomes more reducing over time. It causes reductions of the ferruginous coatings i.e. iron oxyhydroxide on grains releasing adsorbed arsenic which then spread out to surging water table. Thus the origin of arsenic rich ground water is a natural phenomenon (Chowdhury, 2002).

The arsenic contamination of ground water has been widely reported in Bangladesh since 1993. This has become a serious public health problem. Prolonged intake of arsenic contaminated water is well documented in having detrimental health effects. Since about 95 per cent of the drinking source in Bangladesh is ground water. All the people drinking tubewell water may have concern about arsenic toxicity (Khan and Ahmed, 2002).

Arsenic is a relatively common trace element found in nature. An abundance of 2.87 mg/l of arsenic concentration has been reported from the south-western districts of Bangladesh. The principal manifestations of chronic arsenic poisoning like pigmentation, eruption cracking of human skin have been reported. The source of arsenic in drinking water is yet unknown, but it is speculated that the source of arsenic may have a close relationship with the geological formation.

The detection of arsenic in ground water was a cause for immediate concern for the Government of Bangladesh and the Government immediately recognized this as a National health problem which required all related government agencies to take immediate steps. To control and mitigate the problems arising from arsenic contamination in ground water, the Government has formed three National committees. These are – **National Steering Committee** headed by the Honorable Minister, for Health and Family Welfare, **Arsenic Technical Committee,** headed by Director General of Health Services and a **Scientific Research Committee**, headed by the Chairman, Atomic Energy Commission. The Ministry of Health and Family Welfare is implementing a project on arsenic detection and health survey through the department of Occupational and Environmental Health (DOEH, NIPSOM) has been carrying out patient identification, case management, water tasting, research, training and awareness activities since 1994. The faculty of DOEH was trained on various aspects of arsenic contamination from School of Environmental Studies (SOES), Jadavpur University, Kolkata (Khan and Ahmed, 2002).

Arsenicosis diseases in Bangladesh is a serious health hazard for the people. Arsenicosis is the outcome of groundwater arsenic poisoning. Due to this diseases, a number of socio-economic and psychological problems have arisen in the country.

2.6. Oxidation and Reduction Theory of Arsenic

Oxidation Theory: Oxidation of aresenopyrite or arsenic-rich pyrite minerals.

The most important ores of arsenic are arsenic pyrites, realgar and orpiment. Arsenopyrites release arsenic in groundwater by oxidation as shown in the following equations:

$$4\ FeAsS + 11\ O_2 + 6\ H_2O \rightarrow 4\ FeSO_4 + 4\ H_2AsO_3^- + 4\ H^+ \qquad [1]$$

$$4\ FeAsS + 13\ O_2 + 6\ H_2O \rightarrow 4\ FeSO_4 + 4\ H_2AsO_4^- + 4\ H^+ \qquad [2]$$

In this process, oxidation of soils may be caused by aeration due to seasonal water level fluctuations or water table lowering by large-scale withdrawal of ground water. Soils may also be oxidized by infiltration of water saturated with dissolved oxygen.

Charkraborti (1996) and his colleagues studied and confirmed the presence of arsenic in iron pyrite sediments. They suggested that the high volume extraction of ground water in the region has exposed the deltaic sediments to air, which through oxidation reaction causes the decomposition of iron pyrites to ferrous sulfate ($FeSO_4$), ferric sulfate ($Fe2(SO_4)3$) and sulfuric acid. The Process frees up arsenic which is then oxidized into arsenite and arsenate both of which are soluble in ground water (Islam, 1998). In the last two decades, the Green Revolution at Bengal, had lowered the ground water level and thus the release of arsenic (Lepkowski, 1998).

The oxidation of arsenopxrite or ferrous hydroxides rich in arsenic present the Bengal Delta sediments may be responsible for the release of arsenic oxides in solution to the groundwater. The subsequent migration of this arsenic contaminated groundwater through these deltaic sediments may be one of the leading causes of arsenic contamination of the study area.

Reduction Theory: Reduction of arsenic-rich iron-oxyhydroxides.

According to reduction theory arsenic can be mobilized from soil in a reducing environment. In the reducing zone at low redox potential, insoluble iron minerals are partially reduced to soluble iron and similarly manganese is partially reduced to Manganese State. On dissolution of the minerals, the adsorbed arsenic is released into pore water. Thus reduction and subsequent dissolution of iron, manganese and other minerals that contribute to sorption and retention of arsenic can provide an explanation of the mechanism of arsenic contamination of groundwater. The reduction process also converts precipitated and adsorbed As(V) into more soluble As(III):

$$H_2AsO_4^- + 3\,H^+ + 2e^- \rightarrow H_3AsO_3 + H_2O \qquad [3]$$

In the reducing soil environment, arsenic will dominate in pore water as As(III). Further reduction of As(III) in the presence of sulfides will immobilize arsenic in soils with the formation of arsenic sulfide precipitates:

$$2\,H_3AsO_3 + 6\,H^+ + 3S^{2-} \rightarrow As_2S_3 + 6H_2O \qquad [4]$$

$$2\,As_2S_3 + 4e^- \rightarrow 4\,AsS + 2\,S^{2-} \qquad [5]$$

Arsenic from realgar (AsS) and orpiment (As_2S_3) can also be released in water by oxidation as shown in Equations 1 and 2.

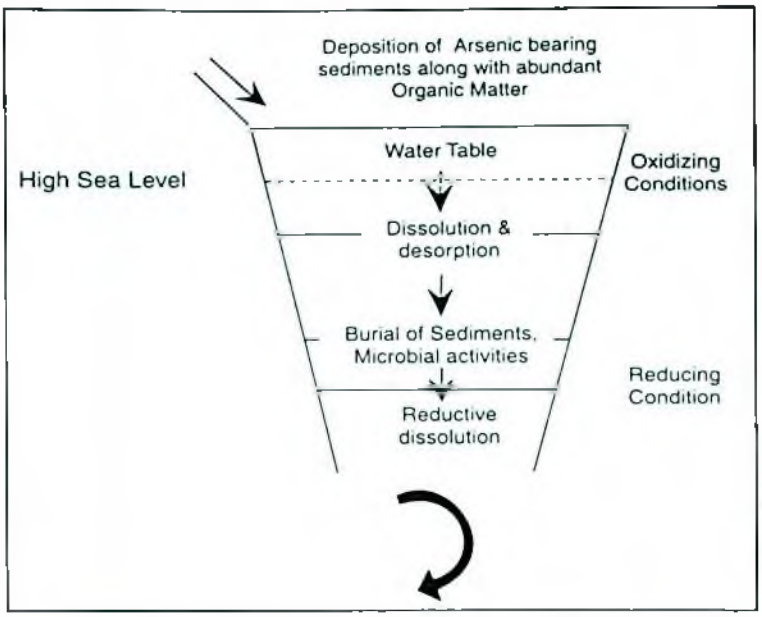


Figure-2.3 : Oxidation and Reduction of Arsenic Process

Source: Ahmad, 2000

The oxidation theory however fails to explain the increase in arsenic level in deeper wells and anoxic condition. Ross Nickson of the University College London suggested that in deep wells, arsenic is released when arseniferous iron-oxyhydroxides are reduced in anoxic water. Nickson observed that arsenic-rich ground water is mostly restricted to the alluvial aquifers of the Ganges Delta and concluded that the source of arsenic must lie in the Ganges source region upstream of Bangladesh (Tsushima, 1998).

CHAPTER THREE

3. REVIEW OF LITERATURE

3.1. Introduction :

Arsenic is a ubiquitous and naturally occurring element present throughout the earth's crust. It is found in a variety of forms in soil, water, air and food. Arsenic is quite a rare element (in 51st place in the list of the crustal abundance of elements). Both toxic and inorganic arsenic are present in the environment, but the inorganic forms are considered much more toxic. It is an established human carcinogen. Arsenic is tasteless, colorless and odorless even at high concentrations in water. Soil is not detected easily. It is one of the most abundant and terrestrial elements on earth. Arsenic "the king of poison" is presently a mystery and myth with a synonym toxic.

The arsenic contamination in groundwater is now-a-day a major environmental hazard and national threat not only the country but also the whole country specially in developing country. At environmental health disaster is unfolding in Bangladesh. Millions of persons in many districts are drinking groundwater with arsenic concentrations for above acceptable levels. Thousands of people have already been diagnosed with poisoning symptoms, even though much of the at-risk population has not yet been assessed for arsenic related health problems.

3.2. Historical Review :

Arsenic is widely distributed in nature, even though it is one of the less plentiful elements in the earth's crust. Compounds of arsenic were known in ancient times, one of the earliest references to them being in the writings of Greek philosopher Theophrustus (C.370-287 B.C). The discovery of the

element is generally credited to Albertus Magnus (C.1206-1280.), the German philosopher and writer on physics. In 1733 George Brandt established that white arsenic was actually the oxide of the element, and in 1817 Jons Jakob Berzelius determined the weight relationship of arsenic to other elements (Colliers Encyclopaedia Vol. 2, p. 704-5).

In the 4th century BC Aristotle wrote of a substance called *Sandarachë*, now believed to have been the mineral realgar, a sulfide of arsenic. Then, in the 1st century AD, the writers Pliny the Elder and Pedanius Discorides both described *auripigmentum*, a substance now thought to have been the dyestuff orpiment, As_2S_3. The first clearly authentic report of the tree substance was made in 1649 by Johann Schroeder, a German pharmacist, who prepared arsenic by heating its oxide with charcoal. Later Nicolas Lemery, a French physician and chemist observed the formation of arsenic when heating a mixture of the oxide, soap and potash. By the 18th century, arsenic was well known as a unique semimetals (Encyclopaedia of Britanica Vol. 15, p. 984).

Over the last two decades in Bangladesh, untreated tube well water was heavily promoted and developed as a safe and environmentally acceptable alternative to microbiologically unsafe untreated surface water. In the 1980s, scientists began finding evidence of arsenic contamination, but only very recently (mid 1990s) has the crisis emerged into broad public awareness. The origin of the arsenic pollution is geological in this case the arsenic is released to groundwater under naturally occurring aquifer conditions.

Groundwater is the preferred source of drinking water in rural areas, particularly in developing countries, because treatment of the same including disaffection, is often not required and its extraction system can be placed

near consumers. The groundwater of vast areas in the Ganges Delta in West Bengal and Bangladesh in highly contaminated by arsenic. The problem of arsenic contamination of groundwater is more serious in Bangladesh, where the groundwater in 59 of the 64 districts is contaminated with arsenic and about two-third of the population is exposed to "the biggest mass-poisoning case the world has ever known" (Washington Post-2001). The water from deep wells in these areas may not be initially contaminated by arsenic, but there is every reason to fear that in course of time the contaminated groundwater from upper level may ultimately affect the water of the lower level too.

Present study deals with the cause of arsenic in water and soil and relation with other geological and socio-economic and psychological parameters according to geo-environmental analysis. Such study is rare in Bangladesh.

At the end of the year 2001, the claws of arsenic have also threatened the living of thousands of people of 28 municipalities. The number of patients seriously affected by arsenic from drinking water has now risen to thousands (Chowdhury, 2001). Some 61 out of 64 districts across the country face the menace of arsenic poisoning. In end of 2001, Bangladeshi officials admitted that some 80 million people more than 65 percent of the country's population live in the arsenic contaminated areas. Thousands of crowed villages with their golden paddy fields and steamy banana groves are threatened by poisoned water. Due to the sheer magnitude of the catastrophe, a resource poor nation like Bangladesh is now struggling not quite successfully, to cope with problem caused by arsenic contaminated tube-wells in the rural areas (Chowdhury, 2001).

The tubewell was promoted as a safe source of water in the 1970s in Bangladesh, which was affected with water-borne diseases. It was cited as success story for providing the safe drinking water at a cheap rate. But the story changed in the late 1980s when first arsenic patient was found at a village in Faridpur (Shehab, 2001). In recent times, arsenic contamination of ground water in Bangladesh has a reached an alarming level.

"..... Bangladesh is having the biggest mass poisoning in history. Dangerous levels of arsenic have been found in the ground water ..... affecting millions of people who drink tube-well water contaminated by arsenic ....." reported by the International Herald Tribune in its 11 November 1998 issue (Chowdhury and Murshed, 2000). In Bangladesh, an estimated 268 upazillas out of 465 (now 469, August 2003) have been affected with significantly high concentrations of arsenic. Arsenic in groundwater is present in excess of the safe limit set for Bangladesh. It is now recognized that organic is a serious health hazard. It reviews some of the arsenic removal technologies being tried and tested in Bangladesh.

The southern, central and north-eastern regions of Bangladesh have been most severely affected by arsenic contamination of shallow tubewell water. In Bangladesh tubewell water extracted from shallow aquifers is the primary source of drinking/cooking water for most of its population. It is generally known that the aquifer materials and water contain arsenic as well as non-toxic elements. But arsenic, a deadly toxic element if it exists above safe level, then it is serious concern for mankind. An estimated 7.5 to 8.0 million hand tubewells constitute the backbone of rural water supply in Bangladesh. The urban water supply is also heavily dependent on groundwater. An estimated 28 million people are exposed to arsenic concentrations in tubewell water above the Bangladesh drinking water standard of 50 ppb.

The arsenic contamination of groundwater has become a major calamity for Bangladesh. The alluvial aquifer that underlies the Ganges-Brahmaputra river basin contains arsenic in mineral form and has been widely tapped for obtaining drinking and irrigation water. Over a period of about 20-25 years about four million wells have been installed to utilize the groundwater from deeper aquifer layers, typically less than 200 m deep. Exploitation of groundwater from these wells has resulted in mobilizing the arsenic and led to mass poisoning in the region, which is defined by the generic term arsenicosis. Presence of arsenic from natural sources in the groundwater is not unusual and has been documented in other parts of the world (Adeel, 2001). The presence of arsenic in the tubewells in Bangladesh has a natural origin due to the hydrogeologic characteristics.

Arsenic contamination of drinking water has been reported from many parts of world. In some arsenic affected areas, substitution of drinking water source by a safe and easily available one may not be possible during past or all of the year or may be very expensive (Johnston and Heijned, 2001). Groundwater is available in shallow aquifers in adequate quantity in the flood plains for development tubewell based water supply for scattered rural population. Bangladesh achieved remarkable successes by providing drinking water at low cost to the rural population through sinking of shallow tubewells in flood plain aquifers. Unfortunately arsenic contamination of shallow tubewell water in excess of acceptable limit has become a major public health problem in Bangladesh. Thousands of people have already shown the symptoms of arsenic poising and several millions are at risk of arsenic contamination from drinking tubewell water. Arsenic removal may be a more appropriate water supply option in these situations.

The technologies available for arsenic removal from water supplies include chemical precipitation through coagulation filtration and softening activated alumina or carbon adsorption, ion exchange and processes with membranes such as reverse osmosis, electrodiatysis and nanofiltration. Most of these technologies have not been tested at full-scale, with present experience only at the laboratory and pilot-plant scale. when these advanced technologies are tested in a more realistic scenario with complex matrix water such as hardness, sulfate, total dissolved solids, selenium, nitrate, fluoride, chloride, calcium, manganese, iron, sulphate, orthophosphate natural organic materials and suspended materials. Some of these technologies might present important limitations and the removal efficiency may drop significantly.

The only technology for which there is experience at full scale is coagulation filtration; these processes would be used in Bangladeshi water treatment utilities for arsenic removal. Coagulation filtration processes remove through chemical sorption and particle removal. In 1970 the first of four water treatment plants for arsenic removal presently in operation was build (Sancha, 1998). The most common technologies utilized the conventional processes of oxidation, co-precipitation and absorption onto coagulated flocs, adsorption onto sorptive media, ion exchange and membrane techniques for arsenic removal.

3.3. Uses of Arsenic :

Arsenic is a chemical element in the nitrogen family existing in both gray and yellow crystalline forms. Although compounds of arsenic were known as early as the 4th century B.C., the element was not identified as such until 1649.

Arsenic was used in Aristotle's time to harden copper (Encyclopaedia Britanica). A vast literature exists regarding the hypotheses that arsenic poising was the cause of Napoleon's death, due to its presence in the green pigments of the wallpaper. The French Emperor Napoleon Bonaparte was sent into exile on the island of St. Helena, following his defeat at the battle of Waterloo. Upon the death of Nepoleon in 1821, it was announced that he died of stomach cancer, but many people believed that he was slowly poisoned with arsenic. In the middle ages, arsenic was commonly used as a suicidal and homicidal agent. A well-known case in Sweden is King Erik XIV, the eldest son of Gustav Vasa, who died in 1577, after a week of chest and stomach pains; it was probably Erik's brother Johan III who ordered the assassination.

Also in Bangladesh, it was long been known that arsenic is a deadly poison and in the nineteenth century, a famous case is the Emperor Vawal Raza, who was poisoned by his wife but fortunately he was not died. White arsenic sublimes on heating and it has been claimed that candles with prisoned wicks were used to poison Leopold-I of Austria in 1970. In fact, death lamps in which oil wax impregnated with arsenic and other substomachs are burned have been used to poison victims slowly.

Orpiment and realgar have long been used as depilatories in the leather industry. When orpiment is rubbed on silver, it gives the surface a golden color. Orpiment thus appears to have one of the properties attributed to the philosophers' stone, and it was there an important materials for alchemists.

The toxic quality of arsenic also has been known since ancient times. In the human body it accumulates in the nails and the hair, where it can be detected even in bodies of person long dead by the Marsh test. The acute symptoms

are diarrhea and cramps. In cases of chronic poisoning, anemia and paralysis may appear. If there is prolonged contact with the skin tumors can develop. BAL (British Anti-Lewisite) was developed as an antidote against the arsenic containing war gas Lewisite, but it also proved useful in treating common arsenic poisoning. In medicine, 4 aminobenzene arsenic and 4 hydroxybenzene arsenic compounds are used in certain infections. Although its water-soluble compounds are poisonous in small doses they are valuable in medicine for the treatment of diseases of the skin and respiratory organs. Nevertheless, over the past 150 years arsenic also has been used in syphilis, epilepsy, psoriasis, trypanosomiasis, and amoebiasis causes by micro ranisms, malaria and diabetes. Arsenic also been included in medical tonics and as late as the 1959, arsenic trioxide (As_2O_3) was as list of drugs approved in Sweden. arsenicals are used some chemotherapeutic agents. Arsenic might still be used in homeopathic medicine and in some herbal preparations. The best known is salvarsan, an antisypphilis drug. Commercially arsenic is added to lead to harden it and in the production of herbicides, pesticide and vermicide in agriculture.

The principal use of elemental arsenic is as a constituent of alloys. Added to copper-base alloys, arsenic forms arsenic brasses and bronzes, speculum metal, and alloys for high temperature uses; added to lead-base alloys it is used for battery grids, bearings, and cable sheaths; and alloyed with elemental lead it is used for Harding short. Arsenic compounds are also sued in the manufacture of rodent poisons, glassware, for preserving hides and museum specimens and in tanning leather. In forestry, it is used as wood preservative. It is also used in certain paints, wallpaper, ceramics and as colouring materials e.g. King's Yellow, mineral blue, parirs green etc.

Table-3.1: Some uses of arsenic within different sectors (Nriagu and Azcue, 1990)

Sector	Uses
Agriculture	Pesticides, insecticides, defoliants, Wood preservatives, debarking trees, soil disinfectant.
Livestock	Feed additive, disease prevention (swine dysentery, heart worm infections, cattle and sheep dips, algaecides).
Medicine	Antisyphilic drugs, treatment of trypanosomiasis, anti amoebiasis drugs.
Electronic	Solar cells, opto-electronic devices, semiconductor applications, light emitting diodes in digital instruments.
Industry	Glassware, electro photography, catalysts, pyrotechnics, antifouling paints, dyes, soaps, ceramics, pharmaceutical sustances
Metallurgy	Alloys e.g. automotive body solder & radiators, battery plates as hardening agents

Elemental arsenic has few practical uses, one of which is to impart more nearly spherical shape in the manufacture of lead shot. It is also used in certain alloys to increase strength at elevated temperatures, in bronzing, and in pyrotechnics. All naturally occurring arsenic consists of the stable isotope arsenic 75; the radioactive isotopes arsenic -72; -74 and –76 have been used in medical diagnostic procedure (Encyclopaedia Britanica, Vol. 1).

3.4. General Properties of Arsenic:

Arsenic, its chemical symbol is As. Arsenic and its compounds are ubiquitous in nature and exhibit both metallic and nonmetallic properties. It is fragile in nature crystalline and gray or tin white in colour. It has three allotropic forms that are yellow, black and gray. Arsenic is rapidly oxidized to arsenous oxide (AS_2O_3), when heated with the order of garlic. It is a group VA of the periodic table with atomic number 33 and atomic weight 74.9216,

Chemically this elements closely resembles to phosphorous antimony. Gray arsenic, the ordinary state form, has specific gravity of 5.73 g/cc and yellow form has 2.03 g/cc. It sublimes at 610°C under atmospheric pressure admelts at 814°C under a pressure of 36 atmospheres (Encyclopedia Americana Vol. 2).

Arsenic exhibits a broad range of chemical reactivity with an ability to form alloys with other elements and covalent bonds with carbon, hydrogen and oxygen. It participates readily in oxidation-reduction, methylation-demethylation and acid-based reactions. Arsenic burns in air giving off an odour of garlic and dense white fumes of arsenic trioxide (AS_2O_3). Arsenic trioxide is the most important commercial compound of arsenic. The solubility of arsenic trioxide in water is fairly low about 2 per cent at 25°C and 8.2 per cent at 98°C. It highly soluble in both hydrochloric acid and alkali.

Arsenic occurs naturally in all environmental media, air, soil and water and usually presents in the form of compounds with sulfur and many metals (copper, gold, cobalt, lead, zinc etc). Among 150 species of arsenic bearing minerals, the most common are arsenopyrite (FeA_SS), enargite ($CU_3A_sS_4$), realgar (AsS) and orpiment (AS_2S_3). Chemically arsenic compounds mainly are of two types, inorganic and organic. Inorganic arsenic is more toxic than organic arsenic: trivalent inorganic (arsenite) is more hazardous than the pentavalent form (arsenate) (Khan and Ahmed, 2002). Arsenic is exist in four forms in water. Those are arsenite (trivalent), arsenate (pentavalent), monomethyl arsenic acid (MMAA) and dimethyl arsenic acid (DMAA), but in ground water arsenic predominantly occurs in the tri and pentavalent forms.

Arsenate (as $H_2AsO_4^-$ and $HAs\ O_4^-$) is the predominant form of arsenic in well-oxidized waters; while arsenite occurs predominantly as H_3AsO_3 and $H_3AsO_3^-$ in reduced environments, although because of the relatively slow redox transformations both arsenate and arsenite are often found in either redox environment. Arsenite is twenty five to sixty times more toxic than arsenate and has been more reported to be more mobile in the environment. The most poisonous forms are arsenic trioxide As_2O_3 and sodium arsenate ($NaAsO_2$). Arsine (AsH_3) resulting from electrolytic process is extremely toxic often causing hemolysis (Philp, 1995).

Basic Terms of Arsenic:

Allotropic Forms. Elemental arsenic exists in three allotropic forms. Black arsenic, which is amorphous, is obtained by the thermal decomposition of arsine (A_sH_3). Yellow arsenic, which consists of As_4 molecules, is obtained when arsenic vapor is chilled rapidly. Yellow arsenic is quite volatile and is more reactive than metallic arsenic, to which it transforms easily. Gray, metallic arsenic has a layered crystal structure of high density. It is an excellent conductor of heat, but its electrical conductivity is only about 5 percent that of copper.

Reactions. Elemental arsenic burns at 400°C (752°F) to form the senquioxide As_4O_6. It also reacts readily with chlorine and sulfur and with most metals to form arsenides. Arsenic does not dissolve in hydrochloric acid in the absence of oxygen and dissolves only slowly in its presence. It is insoluble in dilute sulfuric acid but reacts with the hot concentrated acid to form the sesquioxide but no sulfate. Warm, dilute nitric acid attacks it to form $H_3\ A_sO_3$, and the concentrated acid forms $H_3\ A_sO_3$.

Tests. The best-known compound of arsenic in its – 3 oxidation state is arsine, AsH_3, a colorless gas. Arsine is formed by hydrolysis of an arsenide, by reduction of arsenic compounds by zinc or tin in acid solution, or by electrolysis, using a mercury or lead cathode. In the Marsh test for arsenic, after formation of arsine, the gas is decomposed by heating in a small glass tube. The formation of a metallic mirror on the tube walls is proof of the presence of arsenic. A second test for arsenic, the Guizeit test, depends on the reaction of arsine with a test paper impregnated with mercuric chloride or bromide. Arsine produces a brown coloration of the paper. Because arsine is extremely poisonous, inhalation of the gas must be avoided in making tests.

Oxide. The oxides of arsenic are similar to those of phosphorus. Arsenious oxide, which is composed of tetrahedral As_4O_6 molecules, is known commercially as white arsenic or simply as arsenic. It is soluble in some organic solvents and is slightly soluble in water, in which is forms solutions of arsenious acid (H_3AsO_3). Arsenious oxide is amphoteric but has a slightly greater acidic character. It dissolves readily in alkalis to form arsenites. Arsenious oxide is extremely toxic (0.06 to 0.2 gram usually is fatal), although repeated consumption of small doses may lead to a higher tolerance. Suspensions of magnesium or ferric hydroxide are used as antidotes because they form insoluble arsenites.

Unlike phosphorus, arsenic does not react directly with oxygen to form arsenic pentoxide, As_2O_5. The pentoxide can be synthesized by oxidation of arsenic with nitric acid. On heating the pentoxide readily loses oxygen to form arsenious oxide. The pentoxide is very soluble in water, forming solutions of arsenic acid ($H_3AsO4.\ ½H_2O$).

Holides. Arsenic trihalides are prepared by direct combination of the elements or by the reaction of the oxide or sulfide with a halogen. Arsenic does not form oxyhalides. The only pentahalide known is arsenic pentafluoride. The halides are reduced by hypohosphite, sulfurous acid, chromous chloride, or cuprous chloride. The volatility of arsenic trichloride has led to separation of arsenic from antimony and other heavy metals by volatilization of arsenic in a stream of chlorine.

Arsenates and Arsenites. Arsenates closely resemble the corresponding phosphates in solubility and crystal form, but they hydrolyze more than the phosphates do. Sodium arsenate, $Na_3AsO_4 \cdot 12H_2O$, is used in printing inks, in dyeing textiles, and in preparing arsenate, such as lead and calcium arsenates, that are used in insecticides. Potassium dihydrogen arsenate, called Macquer's salt, is used in the manufacture of flypaper and insecticides, in the dyeing of textiles, and in the preservation of hides. Sodium metaarsenite, $NaAsO_2$, is used in making soaps and insecticides, in dyeing and in preserving hides. Arsenites of copper are used in Paris green as an insecticide and in Scheele's green as a pigment.

Sulfides. Arsenic forms the sulfides As_4S_3, As_4S_4 (red arsenic), As_2S_3 (yellow arsenic), and As_2S_5. The sulfides are acidic and dissolve in strong bases. Both red and yellow arsenic were used by the Greeks and Romans as color pigments. These compounds are still used for colors.

Organic Compounds. Organic compounds containing arsenic-carbon bonds can be prepare in numerous ways. The simplest way is to use Grighard reagents and arsenic halides. The trialkyl and triaryl arsines form many compounds with heavy transititon metals. They also react with alkyl and aryl halides to form quaternary salts.

Effects on the Body. Arsenic causes acute inflammation of the stomach and also affects other parts of the body. Nevertheless, arsenic compounds have been used medicinally at least since the time of Hippocrates in the 5th Century B.C. In 1909 the German bacteriologist Paul Ehrlich discovered that an organic compound containing arsenic could cure syphilis. However, antibiotics have now replaced arsenic compounds in most treatments. (Encyclopaedia of Americana, Vol. 2.)

Table- 3.2: Basic Information and Properties of Arsenic

Chemical Symbol	As
Forms	Three
	a. yellow
	b. black
	c. gray
Place in the periodic chart	Group VA
Atomic number	33
Atomic weight	74.9216
Isotope, stable	75
Isotopes, unstable	70, 71, 72, 73, 74, 76, 77, 78, 79, 81
Melting point (°C)	814 (at 36 atmospheres)
Boiling point (°C)	615 (Sublimes)
Density (grams per cc)	
gray form	5.73
yellow form	2.03
Hardness (Mohs' scale)	3.5
Abundance in lithosphere (percent)	0.0005
Oxidation states	-3, +3, +5
Convalent radius	121 ppm
Ionic radius (As^{3+})	69 ppm
Metallic radius	139 ppm
Electron configuration	2-8-18-5 or
	$1S^2\ 2\ S^2\ 2p^6\ 3S^2$
Smell	Garlic odour
Principal ores	As_5S_2 (Realgar)
	AS_2S_3 (Orpiment)
	FeAsS (Arsenopyrite)

* Maximum permissible level (in drinking water)

Bangladesh	0.05 mg/l
WHO	0.01 mg/l

* Arsenic cannot be found in nature as a free element
* As many as 150 species of arsenic bearing minerals exist in the earth.
* Arsenopyrite has been primarily identified as the main source of arsenic pollution in the groundwater of Bangladesh.
* According to availability of natural elements in environment the position of arsenic is 20^{th}.
* Arsenic is found in atmosphere, in the aquatic environment, in soils and sediments and inorganisms.
* Per litre natural water contains 1-2 micrograms of arsenic.
* High level of arsenic exists in sea-water.
* Usually a man can receive arsenic up to 150 microgram for per kilogram weight of his/her body without any affect.
* Arsenic compounds are mainly used in agriculture, forestry and industrial processes (i.e. used in the preparation of dyes, poisonous gas, transistor, as a component of semi-conductor; as a preservative in tanning and in the industry of textile, paper etc.

Source : Colliers Encyclopaedia Vol. 2
Encyclopaedia Americana Vol. 2
Encyclopaedia Britanica Vol. I

3.5. Source and Occurrence of Arsenic:

Arsenic contamination is a global problem. The presence of arsenic is ubiquitous, it is the 33^{rd} most commonly occurring element with an average concentration of 2 ppm in the earth's crust (Azizian et al., 2002). It occurs are results of geological processes. Arsenic is commonly found in nature combined with other elements to form sulfides (arsenides, sulfoarsenides and arsenites) and less frequently oxides and oxychlorides. The minerals most frequently encountered are arsenopyrite (FeAsS), loellingite ($FeAs_2$), enorgite (CuS, As_2S_5), orpiments (As_2S_3) and realgar (As_4S_6) (Azizian et al., 2002).

The Bangladesh arsenic contamination is possibly the largest mass poisoning case in the world now. The "Green Revolution" has been identified

theoretically to be the recent cause of the problem which has involved large scale unplanned withdrawal of groundwater, gradually denuding the arsenic deposited under the fertile delta of Bangladesh millions of years ago by the rivers from the Himalayas or some other source.

Arsenic contamination in ground water in West Bengal has been found in 7 districts. Most of the arsenic contaminated areas of West Bengal are in the region of alluvial formation. The source of arsenic contamination in these 7 districts is noted to be geological. Bangladesh is geographically attached with West Bengal and having similar aquifers and socio-economical background. The alluvial formation in Bangladesh has close geological affinity as those encountered in West Bengal. West Bengal and Bangladesh clearly indicate that in the region of alluvial sediment there is existence of pyrite and this pyrite is rich in arsenic. Due to heavy ground water withdrawal and fluctuation of water table from pro monsoon to post monsoon and also due to thousands of bore holes, the underground aquifer is aerated and the pyrite decomposes, the acid released due to this decomposition leaches out arsenic from pyrite. The following flow diagram shows the transformation steps.

Table-3.3: Source and Occurrence of Arsenic

SEDIMENTS WITH TRACES OF ARSENIC FROM HIGHLAND

↓

DEPOSITED IN THE BACKSWAMPS OF RIVERINE SEDIMENTS OF UPPER DELTA PLAIN SHELF/CLAYSTONE WITH ARSENO-PYRITE

↓

WEATHERING

↓

FORMING	COMING IN CONTACT	SLIGHTLY SOLUBLE
ARSENIC TRIOXIDE	→	ARSENOUS ACID
(As_2O_3)	WITH GROUND WATER	H_3AsO_3

OXIDATION ← DUE TO HEAVY WITHDRAWAL OF GROUND WATER AND FLUCTUATIONS FROM PRE TO POST MONSOON THE WATER TABLE DROPS, TURNS ANAEROBIC CONDITION TO AEROBIC CONDITION IRON PYRITE OXIDISED.

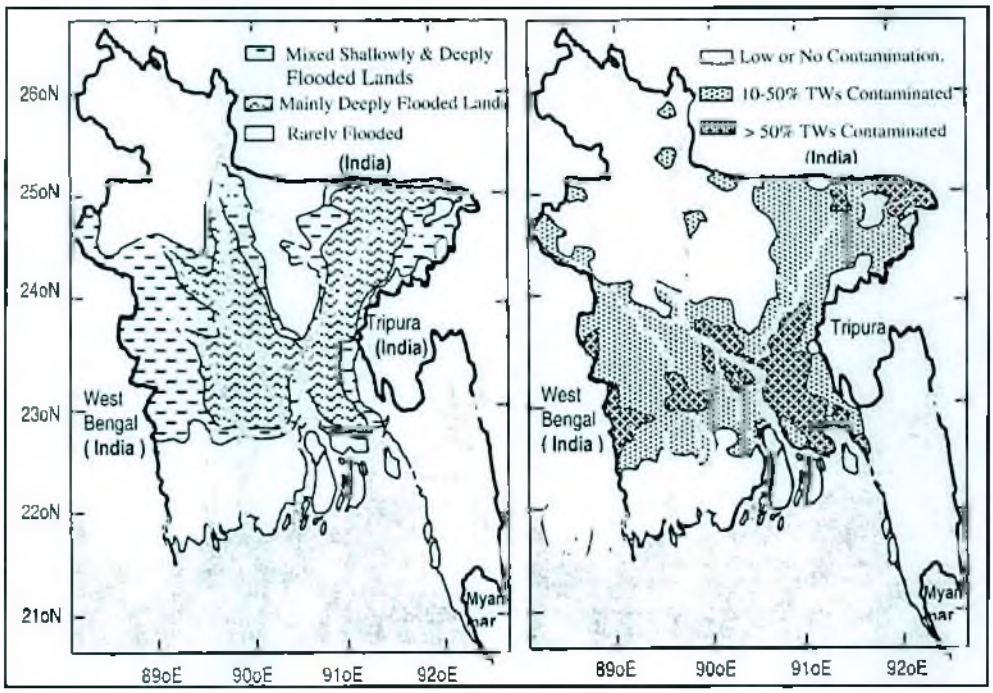
FORMING	COMING IN CONTACT	READILY SOLUBLE
ARSENIC PENTOXIDE	→	ARSENIC ACID
(As_2O_5)	WITH GROUND	WATER (H_3AsO_4)

Source : Khan and Ahmed (2002), p. 341.

3.5.1. Natural sources of arsenic

Arsenic occurs mainly in the As (V) and As (III) oxidation states with As (V) dominant (Sancha, 1998). The arsenic affected areas of West Bengal are lying on a sediment of Younger Deltaic Deposition (YDD) which extends eastward towards Bangladesh covering the approximate area of the 41

districts which lie mostly in the Atrai, Meghna and Gangetic floodplains and the tidal regions (DCH, 1997). Occurrence of arsenic in ground water depends on local geology, hydrology and geochemical characteristics of the aquifer materials, where principal causes of arsenic contamination of groundwater is due to reduction of arsenic rich iron oxyhydroxide in anoxic groundwater (Nickson, et al., 1998; Bhattacharya, et al., 1998). The source of the aqueous arsenic is believed to be aquifer sediments where organic matter driven reductive dissolution releases arsenic to groundwater. Studies of the rocks, sediments and groundwater in Bangladesh; and marine sediments in the Bay of Bengal show that all those contain arsenic. The provenance of the sedimentary rocks deposited in the Bengal Basin are the rocks in the catchment areas of the three great river systems, the Ganges, the Brahmaputra and the Meghna rivers (Alam, 2000). There are some direct and indirect references of occurrences of arsenic and arsenic related minerals in the upstream of the rivers carrying water and sediments in Bangladesh (DPHE, BGS and MML, 1999). The probable provenance of arsenic in Bangladesh and the surrounding areas are those rocks, the Ganga-Padma and Brahmaputra Jamuna systems in Bangladesh carry 2.4 billion tons of sediments, a part of which is deposited in the flood plains each year (Ahmed, 2000). Excessive withdrawal of groundwater creates many hazards and arsenic hazard in Bangladesh is one of those (Alam, 1997). The comparison between deeply flooded areas in Bangladesh and the areas having more than 10 and 50 percent of the tubewell contaminated by producing arsenic (more than 0.05 mg/l) as demarcated in Map 3.1 which shows that the deeply flooded areas are mainly arsenic problem areas of Bangladesh (Ahmed, 2000).



Map-3.1: Comparison of Flooded areas and Arsenic Contaminated Areas of Bangladesh
Source: Ahmad, 2000

The level of arsenic in the soils of various countries of the world have been said to range from 0.1 to 40 ppm. Arsenic in some solid phases within sediments particularly iron oxides, organic matter and sulphides may be the source of arsenic in groundwater. Sediment discharged on the Ganges, Brahmaputra and Meghna Delta and Bengal Fan is the largest in the world due to high relief and tectonic activity of the upper drainage areas and high intensity of land use by man and sea level fluctuation have greatly influenced the deltaic sedimentation pattern through times (Alam, 2000). During worldwide episode of cold climate, the sea level was 120 metres lower than the present (Whitney, 1997). The arsenic affected in West Bengal and Bangladesh are entirely confined within parts of the Ganga Delta east of the Rajmahal hills and further restricted mainly between the Bhagirathi-Hugli and Ganga-Padma river channels. The delta plain

sediments host the aquifers which contain groundwater with high incidence of arsenic. Arsenic contamination of groundwater of a huge magnitude in a terrain, totally devoid of industrial and mining activities, naturally leads to the conclusion that such a phenomenon is essentially due to geological factors. Fluvial deposits may contain arsenic bearing sulphides eroded from mineral deposits in the mountain areas. These phases will tend to stay fixed with the resultant ferroxy hydroxides (Alam, 2000). As these sediments are burried and become anoxic arsenic will be released into the groundwater.

The occurrence, origin and mobility of arsenic in natural have received significant attention in recent years. Mobilization of arsenic in groundwater is governed by the geo-chemical processes involving teaching of continental rocks as well as sediments (Bhattacharya et al., 1998).

Arsenic is the main constituent of more than 200 mineral species, of which about 60 per cent are arsenate, 20 per cent sulfide and sulfosalts and the remaining 20 per cent include arsenides, arsenites, oxides and elemental arsenic (Onishi, 1969). The most common of the arsenic minerals is arsenopyrite, FeAsS, and arsenic is found associated with many types of mineral deposits, especially those including sulfide mineralization. The ability of arsenic to bind to sulfur legends means that it tends to be found associated with sulfide-bearing mineral deposits, either as separate arsenic minerals or as a trace of a minor constituent of the other sulfide minerals. This leads to elevated levels in soils in many mineralized areas where the concentrations of associated arsenic can range from a few milligrams to > 100 mg/kg.

Concentrations of various types of igneous rocks range from < 1 to 15 mg As/kg, with a mean value of 2 mg As/kg. Similar concentrations (<1-20 mg As/kg) are found in sandstone and limestone. Significantly higher concentrations of up to 900 mg As/kg are found in argillaceous sedimentary rocks including shale's mudstone and slates. Up to 200 mg As/kg can be present in phosphate rocks (O'Neill, 1990).

Concentrations of arsenic in open ocean water are typically 1-2 μg/litre. The concentrations of arsenic in unpolluted surface water and groundwater are typically in the range of 1-10 μg/litre. Elevated concentrations in surface water and groundwater of up to 100-5000 μg/litre can be found in areas of sulfide mineralization (Welch et al., 1988). Elevated concentrations (> 1 mg As/litre) in groundwater of geochemical origins have also been found in Taiwan, West Bengal and more recently in most districts of Bangladesh. Elevated arsenic concentrations were also found in the drinking water in Chile, North Mexico; and several areas of Argentina. Arsenic contaminated groundwater was also found in parts of PR China (Xinjiang and Inner Mongolia) and the USA (California, Utah, Nevada, Washington and Alaska). More recently, arsenic concentrations of < 0.98 mg/litre have been found in wells in south-western Finland. Levels as high as 35 mg As/litre and 25.7 mg As/litre have been reported in areas associated with hydro-thermal activity (WHO, 2001).

In nature, arsenic-bearing minerals undergo oxidation and release arsenic to water. This could be one explanation for the problems of arsenic in the groundwater of West Bengal and Bangladesh. In these areas the groundwater usage is very high. It has been estimated that there are about 4-10 million tube wells in Bangladesh alone. The excessive withdrawal and lowering of

the water table for rice irrigation and other requirements lead to the exposure and subsequent oxidation of arsenic-containing pyrite in the sediment. As the water table recharges after rainfall, arsenic leaches out of the sediment into the aquifer.

However, recent studies seem to favour the reduction of FeAs oxyhydroxides as the source for arsenic contamination in groundwater (Nickson et al., 1998; BGS, 2000; BGS & DPHE, 2001). Arsenic forms co-precipitates with ferric oxyhydroxide Burial of the sediment, rich in ferric oxyhydroxide and organic matter, has led to the strongly reducing groundwater conditions. The process has been aided by the high water table and fine-grainec surface layers which impede the penetration of air to the aquifer Microbial oxidation of organic carbon has depleted the dissolves oxygen in the groundwater. The highly reducing nature of the groundwater explains the presence of arsenic (< 50 per cent) in the water. The "pyrite oxidation" hypothesis is therefore unlikely to be a major process, and the "oxyhydroxide reduction" hypothesis (Nickson et al., 1998; Acharyya et al., 1999) is probably the main cause of arsenic contamination in groundwater. Although the oxyhydroxide reduction hypothesis requires further validation, there is no doubt that the source of arsenic in West Bengal and Bangladesh is geological as none of the explanations for anthropogenic contamination can account for the regional extent of groundwater contamination. During the past 30 years the use of phosphate fertilizers has increased threefold in this region. The widespread withdrawal of groundwater may have mobilized phosphate derived from fertilizers and from the decay of natural organic materials in shallow aquifers. The increase in phosphate concentration could have promoted the growth of sediment biota and the desorption of arsenic

from sediments, and the combined microbiological and chemical process might have increased the mobility of arsenic.

Marine organisms naturally accumulate considerable quantities of organic arsenic compounds. In marine animals the bulk of this arsenic is present as arsenobetaine, whereas marine algae contain most of the arsenic as dimethylarsinoylribosides. Humans are therefore exposed to these arsenic compounds through any diet that includes seafoods.

Some arsenic compounds are relatively volatile and consequently contribute significant fluxes in the atmosphere. It has been estimated that the atmospheric flux of As is about 73540 tonnes/year of which 60 per cent is of natural origin and the rest is derived from anthropogenic sources (Chilvers & Peterson, 1987). Volcanic action is the next most important natural source of arsenic after low-temperature volatilization, and on a local scale it will be the dominant atmospheric source.

3.5.2. Anthropogenic sources of arsenic:

The source of arsenic in groundwater is as yet unknown. But it is now widely believed that the high arsenic levels in the groundwater in Bangladesh and West Bengal (India) have a natural source. Anthropogenic inputs particularly due to the application and use of arsenical wood preservatives (Bhattacharya et al., 1998) as well as pesticides could also lead to significant emission of arsenic in groundwater, especially under anoxic conditions.

The reason why arsenic is coming out with ground water is not completely clear but one reason suggested by many scientists all over the world, that

heavy groundwater withdrawal may be one of the reasons. The United States Geological Survey (USGS) in one of their publications comments, "Mobilization of is sedimentary aquifers may be, in part a result of changes in geochemical environment due to agricultural irrigation." Another view is that due to high use of phosphate fertilizer arsenate of soil might have leached to underground aquifers. Scientists believe this may be true for highly porous soil but for heavier soils little leaching is likely. Moreover iron and aluminum of soil will also form a less soluble arsenate and will bind to soil, so leaching may not occur. A group of scientists believe that due to heavy groundwater withdrawal the underground aquifer is averted and the oxygen is responsible for degradation of arsenic rich source. Abstraction from chalk aquifers over many decades has resulted in the dewatering of the overlying Basal Sand Aquifers allowing air entry and has led to the localised oxidation of pyrite and the acid released during oxidation of pyrite is responsible for the poor quality pore water in the Basal Sands. The rate of oxidation is probably greatest near to wells and bore-holes which allowed ready access of air (Kinniburgh et al., 1994).

Due to heavy groundwater withdrawal the aquifer in aerated and the oxygen decomposed the pyrite (FeS_2) rich in arsenic and the acid released leached out the arsenic in soluble form in groundwater. According to Alam M.K, "Enhanced leaching beneath irrigated lands may be the cause of contamination of groundwater by arsenic. Before the advent of tubewells in Bangladesh people used to depend on surface and near surface water for drinking and other domestic uses. On the other hand, Bangladesh only half century before land resources were enough to grow more food grains to feed her people without intensive cultivation with irrigation by the ground water

development. With the growth of population requirement of water is increasing. Developed countries use more water resource than the developing countries. In USA per person use of water is 80 gallons, UK it is about 60 gallons and in Dhaka city it is 40 gallons per day. It is much easier and economic to develop groundwater than the surface water. As a result, there had been huge development groundwater resources in Bangladesh for drinking, domestic, industrial and irrigation purpose. Records show that from 1961 to 1997, the population has increased from 50 million to 125 million. The country now has 4 million tube wells and about 97 per cent of the people are now dependent on tube well water for drinking purpose. It is now known how much groundwater is being withdrawn both from the shallow aquifers as well as from the deep aquifers. The groundwater table is declining in Bangladesh and it may be and indication that the groundwater withdrawal in some areas in Bangladesh may be excessive. There has been study on the problem of arsenic contamination of groundwater is West Bengal of India and it was reported that excessive withdrawal of groundwater, specially during summer when recharge is low might lead to induce oxidation of aquifer material by increased access of atmosphere oxygen. Under such conditions the arsenopyrite/pyrite grains known to be present in the aquifer material would be decomposed and arsenic will be released into the groundwater. Under such dewatered condition the aquifer may also suck in arsenic liberated from arsenic adsorbed inter bedded clayey layers. Long duration pump tests at six bore holes spread over three districts yielded as much as 80 gms of arsenic over a period of eight hours. Such evidence lend credence to the presently prevalent hypothesis of excessive groundwater abstraction. In this connection it may be mentioned that incidence of arsenic in groundwater increased significantly after the large

scale introduction of shallow irrigation tube well mostly tapping the comparatively arsenic intermediate and shallow zones of aquifer. Excessive withdrawal of groundwater creates many hazards and arsenic hazard in Bangladesh is one of those. Human activities like use of agro-chemicals, pesticides, wood preservatives, industrial sources, mineral processing, acid mine drainage, burning of fossil fuels and other causes may lead to arsenic contamination of water resources (Alam, 2000). The largest sources of pollution from arsenic are agricultural chemicals such as herbicides fungicides rodenticides and insecticides (Nair et al., 2003).

Nitrates from fertilizers and animal wastes are prevalent contaminants of ground water as well as pesticides from agricultural activities. National surveys of this types of nonpoint source groundwater pollution have been made by the U.S. Environmental Protection Agency and U.S. Geological Survey.

Total arsenic emission into the atmosphere from anthropogenic sources is of the order of 30,000 tons/year (Chilvers and Peterson, 1987). Arsenic is a natural contaminant in lead, zinc, gold and copper ores and can be released during the smelling process. For example, in Ghana in Africa, where mining exposed previously burried arsenic containing sulphides to oxidation.

Arsenic is a component of more than 245 minerals. These are mostly ores containing sulphides, along with copper, nickel, lead, cobalt or other metals. The reduction of oxy-hydroxide minerals containing traces of arsenic in the reducing part of sedimentary aquifers as in Ohio, USA, and in Bangladesh.

Arsenic can be present in coal mainly as arsenopyrite at concentration from <1 to> 90 mg/kg. On the sources of arsenic contamination is coal fly ashes.

During combustion arsenic and other chaleophiles (e.g. Cr, Se, Sr. Mo and V) in the coal are volatilized and escaped into the atmosphere which may eventually fall out in the surrounding areas and can cause surface soil contamination (Boyle and Jonasson, 1973).

Wastes from industries of glass and ceramics cements, pigments, enamels, antifouling paints, iron and steel production, textile and fire works. Introduction of organic compounds into aquifers from waste disposal and loss of petroleum products also can lead to $Fe(OH)_3$ dissolution and release of arsenic (Welch, 1998). Wiscinson and South East Pennsylvania in U.S.A. where the sediments are contaminated by industrial waste waters (Clement and Faust, 1981).

From late 1800s to mid 1900s Zn-arsenite Paris green [$3Cvg(AsO_2)_2$, $Cu(C_2H_3O_2)$] (copper occtoarsenite), inorganic arsenicals, usually as pb, Ca, Mg were used extensively as pesticides in orchards. sodium arsenite was used as a herbicide and nonselective soil sterilant, while arsenic acid was used as a cotton desicant. Arsenicals have also been used as silvicides, herbicides and desiccants and increases arsenic concentration. The use of arsenic in agricultural chemicals has been under scrutiny by the Environmental Protection Agency (EPA) for many years, the use of many arsenical pesticides have been banned by EPA. The use of the arsenical disodium methanearsenic acid (DSMA), arsenic acid and Caeodylic acid (CA) are expected to decline. It is also anticipated that there will be less danger by arsenic pollution by arsenic containing pesticides in future (Islam, 1999).

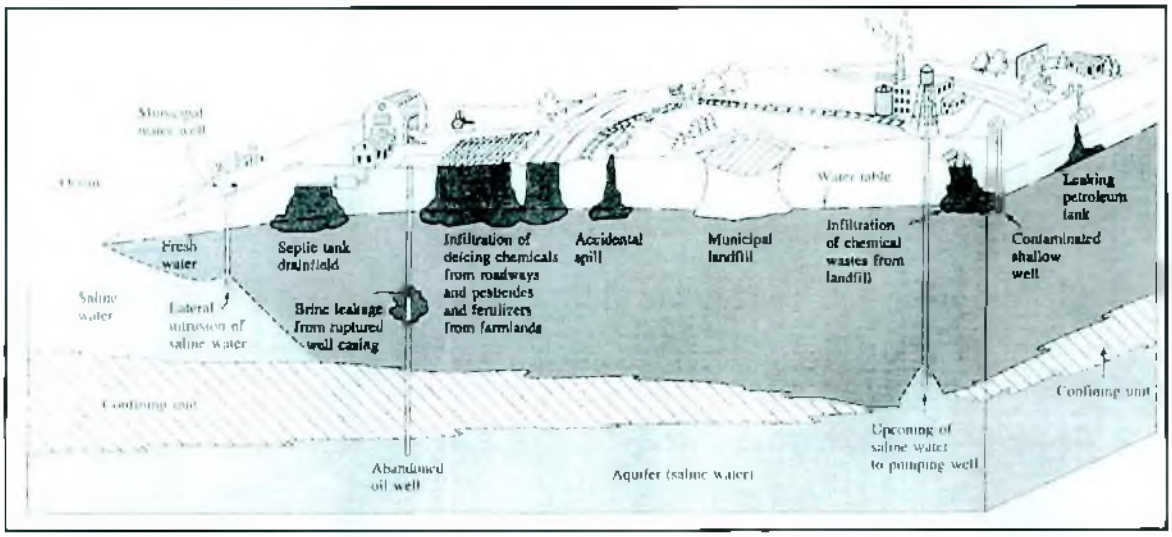


Figure-3.1 : Mechanisms of Ground Water Contamination (Fetter, 1993)

Arsenic trioxide is used for wood preservation. Anthropogenic inputs particularly due to the application and use of arsenical wood preservatives as men as pesticides lead to significant emission of arsenic in groundwater (Bhattacharya et al., 1998). Although disposal of arsenical pesticides has led to high arsenic concentration in ground water (Welch, 1998).

Extensively used on cotton, tobacco and fruit crops, e.g. lead arsenate, calcium arsenate are used for weed killer and increases arsenic concentration. Arsenic is also in sewage sludge some researchers have pointed out concentrations of arsenic from 3 to 46 mg As/kg in sludge from the United States and Netherlands. From 4 to 20 mg As/kg was reported in topsoil from a sewage treatment plant in Canada. Sewage sludge usually contain relatively large amounts of phosphorus from 0.5 ± 0.4 per cent to 1.6 ± .3 per cent which could ameliorate the ill effects of the arsenic present (Islam, 1999).

Another important sources of arsenic contamination particularly soils in Bangladesh is the wooden electric poles which contain 20 kg CCA/m^3 (Chromated copper arsenate) wood. These wooden poles contain about 34 to 38 percent arsenic. Chromated copper arsenate (CCA) is used to protect the poles from biodegradation. About 1.4 million poles were imported used by Rural Electrification Board (REB) for rural electrification. Whenever these poles delay huge amount of arsenic will be released into the environment contaminate soils and surface water, if decaying poles are not properly disposed.

Arsenic concentrations in nonthermal ground water exceeding the current drinking water standard generally result from natural processes and sources. Chemical weathering and upflow of geothermal water are sources of arsenic in ground water. Sulfide mineral oxidation, release from iron-oxide and evaporative concentration are the most commonly identified processes leading to widespread high concentrations. These processes occur naturally but they can be caused or accelerated by human activities.

Chilvers and Peterson (1987) reported that global emission to the atmosphere from anthropogenic sources, especially copper and coal combustion, indirectly contaminates the land and terrestrial waters, while considerable amounts of arsenic are added to the land directly as landfill from the dumping of slag, sewage sludge and industrial wastes. Uses of insecticides, cattle tick dip, feed additives, wood preservatives, etc., cause soil and water contamination both directly and indirectly.

3.6. Arsenic in Groundwater:

Arsenic is a naturally occurring element found in a variety of forms in soil, water air and food. Potential environmental sources of arsenic exposure include household dust, soil, drinking water, foods and airborne particulate. Since arsenic is a natural substance, most of the arsenic in the above sources may be there because arsenic is part of the natural background. The origin of arsenic contamination in ground water may be either natural or anthropogonic. The contamination caused by anthropogenic sources is very limited in space whereas, the natural sources are responsible for widespread contamination.

Bangladesh has swiftly earned the reputation of being one of the most poisoned land in the world as a result of arsenic contamination of ground water. Test have been carried out in almost all the districts of the country and no district or union has reported negative, meaning almost every district has at least some pockets which are arsenic affected. Groundwater is the primary source of drinking water in Bangladesh and neighbour India. A high concentration of arsenic is detected in this ground water. Groundwater contamination is a great concern. It may take decades for contaminated groundwater to naturally return to a useable resource given the slow rates of groundwater movement and recharge. Groundwater contamination emanates from point sources such as waste disposal in landfills and nonpoint or distributed sources such as agricultural application of pesticides.

Arsenic concentrations in fresh waters in unpolluted areas vary but typical values seem to be a few micrograms per litre or less the oxidation state in surface waters in various parts of the world remains largely unknown. The

ratio of trivalent to pentavalent inorganic arsenic ranged from < 0.06 to 6.7 in a few uncontaminated surface water samples having 2.5 to 3.0 mg/l. About 8 per cent of the total arsenic in 2 samples of well aerated stream water (14 and 60 mg/l respectively) was reported by clement and Faust, (1973), to be in the trivalent form. In anaerobic reservoirs all of the arsenic present (0.14 – 1.3 mg/As/l) seemed to be in this form (Islam, 1999).

Quentin and Winkler (1974) found average value of 3 mg/l in river water and 4 mg/l in lake water in Germany. A concentration increase of 0.1 per cent per year is reported for oceanic waters, with a net gain by oceanic waters of $5.66 \times 10^4 - 13.7 \times 10^4$ tons/year (Chilvers and Peters, 1984). Marine algae contain arsenic at concentrations 2000-5000 times greater than of the seawater. The release of arsenic resulting from the activities of man exceeded those due to natural processes.

A number of hypotheses have been put forward to explain the origin of arsenic since the problem was first discovered which includes both anthropogenic and natural sources. Use of fertilizers, pesticides, insecticides, waste disposal, arsenic compound treated wooden poles etc. were blamed as the anthropogenic sources of contamination. On the other hand scientists from the School of Environmental Sciences (SOES), Jadavpur University, West Bengal, India put forward the pyrite oxidation hypothesis as the main mechanism for arsenic which was widely accepted at the beginning. At the International Conference organized by the Dhaka Community Hospital (DCH) and SOES in Dhaka in February 1998 it was agreed that the contamination was of geological origin, not an anthropogenic one. An alternative hypothesis, known as the iron oxyhydroxide reduction hypothesis, was put forward at the same conference. It is relevant

mentioning here that there is a occurrence of groundwater arsenic contamination in Calcutta, West Bengal due to anthropogenic sources which is completely separate from the major contamination found in other parts of West Bengal (Ahmed, 2000).

Sea-water ordinarily contains arsenic concentration ranging from 0.1 to 8 μg/l levels of about 2 μg/l (Penrose et al., 1977; Onishi, 1969; Jhonson and Braman, 1975). Arsenic concentrations in surface and deep water of Atlantic found to be 1.45×10^{-3} and 1.53×10^{-3} μg/l respectively, while those values are 1.45×10 and 1.75×10^{-3} μg/l for Pacific Ocean (Emsley, 1991). Arsenic speciation has also been performed on well water samples from an area in Alaska containing high levels of arsenic (Harrington et al., 1978). In fine samples containing arsenic from 0.52 to 3.6 μg/l, between 3 per cent and 39 per cent of arsenic present was trivalent, the rest being pentavalent. No methylated arsenic compounds could be detected. Forms of arsenic in fresh water are $HAsO_4$; H_2As_4 possibly H_3AsO_3, AsO_4^{3-} or $H_2AsO_3^-$.

Today seawater contains arsenite and arsenate in a theormodynamic disequilibrium (more arsenite that expected) at a concentration of total arsenic of approximately 2 μg/l. As much as 100 years ago determinations of arsenic in marine organisms suggested that the concentration of arsenic in the organisms is much higher than in the seawater. During the past three decades high concentrations of arsenic were found with much improved analytical methods in many marine animals and plants. Bioaccumulation Factors (concentration of As in fresh organisms/concentration of arsenic in seawater) of 1000 are the rules. In exceptional cases this factor assumes values of 200,000. Most of the marine organisms, in which total arsenic had been determined, possess concentrations of arsenic of a few mg/kg and

several up to several hundred mg/kg on a wet mass basis (Irgolic et al., 1998).

Although concentrations of total arsenic can be higher in fresh waters (for example, in hydrothermal areas and regions with sulfide mineralization) than in sea water, in which the arsenic concentration is uniformly approximately 2 μg/l, they are generally much lower than in sea water (U.S. National Academy of Sciences, 1977).

High levels of arsenic have been found in waters from areas of thermal activity. Thermal waters of New Zealand contain up to 8.5 mg/l, geothermal water in Japan contained arsenic levels of 1.8 – 6.4 mg/1 and neighboring streams contained about 0.0002 mg/l. The solubility of arsenic water is usually controlled by redox condition, P^H biological activity and adsorption reactions (Ahmed, 2000).

If a time of arsenic contamination is after 1975 in Bangladesh, a probable explanation is that the changes in geochemical environment due to the high withdrawal of groundwater resulted in the decomposition of pyrites to oxide iron, arsenic sulfuric acid. These oxides are soluble in water containing in acid. In the reducing conditions below the water table and in the presence of organic matter non-poisonous oxides of arsenic are reduced to poisonous oxide forms. The UK/DFID report mentioned that the oxidation of arsenic pyrite is to be a major cause of groundwater arsenic poisoning in Bangladesh rather the 'postulated an arsenic adsorption and oxyhydroxide reduction' hypotheses as the main cause of groundwater arsenic poisoning in Bangladesh. The UK/DFID states that "a number of anthropogenic explanations has been given for the occurrence of arsenic in groundwater.

while it is possible that some may explain isolate cases of arsenic contamination, none of the anthropogenic explanation on account for the regional extent of groundwater contamination in Bangladesh and West Bengal.

3.7 Arsenic in Soil:

The level of arsenic in the soils of various countries of the world have been said to range from 0.1 to 40 ppm (Alam 2000). It is believed that arsenic adsorbed on soil grain under certain conditions causes ground water contamination through desorption (Ahmed, 2000). Arsenic in soil may originate from the parent materials that form the soil and from industrial waste discharges or agricultural use of pesticides. Arsenic is widely distributed in soils, mostly combined with iron, nickel gold and sulphar. Soil is an important natural resource for mankind, but it also serve as an important medium for the accumulation, transformation and migration of toxicants. The total amount of arsenic in soil and its chemical forms has an important influence on plant growth and animal and human health (Nriagu and Azcue, 1990).

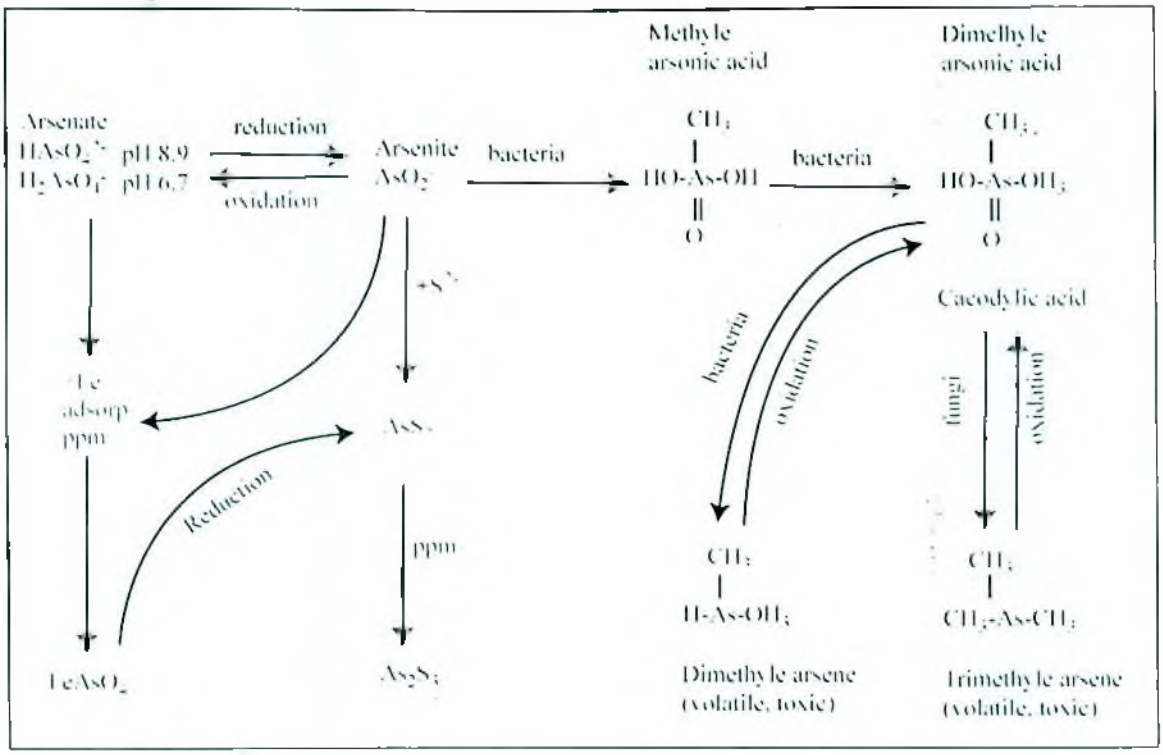


Figure-3.2: Chemical Forms of arsenic and their transformation in soils
Source : Nariqu and Azcue, 1990

Arsenic in soils is highly mobile, resulting in possible groundwater contamination. Any retention of arsenic in soils would occur by adsorption, especially if the soils contained iron aluminum oxides. The most important ores of arsenic are arsenic pyrite, realgar and orpiment. The arsenic level in soil enriched in these ores are often higher than in normal soil. Arsenic concentrations are considerably high in soil and states than the earth crust because of its accumulation during weathering and translocation in colloid fractions. The solid particles (grains) of both igneous and metamorphic rocks often denudation, weathering and erosion when carried down to the depositional domain by transporting agents like water, are termed as sediments. These sediments under the influence of physical, chemical and biological process are transformed into sedimentary rocks. Arsenic in the sediments could be derived from two processes: (a) as the denuded,

fragmented, weathered and eroded particles of parent arsenic bearing minerals from the source regions, (b) as adsorption of arsenic in the sediment grains coating from arsenic rich aqueous solution. Acid Mine Drainage (AMD) from largely coal and to some extent gold mining often contains large concentration of both iron and arsenic due to oxidation of pyrite provided there exists sources of arsenic. The parent materials of soil are usually sedimentary rocks. During the formation of these rocks, arsenic is carried down by precipitation of iron hydroxides and sulphides. Therefore iron deposits and sedimentary iron ores are rich in arsenic. In uncontaminated soils the average concentration of total arsenic is a few mg/kg. Most plants growing on these soils do not accumulate arsenic and therefore have in their tissues arsenic at concentrations below mg/kg on a wet mass basis. In contaminated areas tissues may reach a few mg/kg (wet mass) (Irgolic et al., 1998). Arsenic accumulators, for instance, the mushroom *Laccaria amethystina*, reach concentrations of total arsenic of approximately 100 mg/kg (dry mass) (Irgolic et al., 1998). Arsenic is being added to soils in various ways. Approximately 41 per cent arsenic comes from commercial product waste of the total arsenic added to soils. About 23 per cent come from coal fly ash and bottom ash, 14 per cent from atmospheric fallout, 10 per cent from mine tailings, 7 per cent from smelter, 3 per cent from agrochemical and 2 per cent from manufacturing urban and forest wastes (Islam, 1999). Soils are also concentrated with much arsenic of up to ten to hundred ppm, compared with the fresh rocks of the same type.

Arsenic is inclined to be concentrated to the fine grained beds, there is a possibility that high concentrated arsenic is originally contained in the alluvium sediments. The mechanism reason for the concentration of arsenic

in fine grained sediments and soils before and after sedimentation, must to be clarified. Soils located near smellers have become inadvertently contaminated as soils in old orchards where arsenical sprays were repeatedly used some years ago and soils down wind from industrial sources (Nriagu and Azeua, 1990). As many as 33 sites in 13 ecosystems from California, Colorado, Texas, South Dakota and Montana have arsenic contamination up to 218 mg As/kg as measured in soil, water and sediments samples (Islam, 1999). Arsenic is not static in nature. Oxidation, reduction, evaporation, methyllation and adsorption processes make arsenic available in nature as with various compounds Arsenic is always present in soil, air and water. It is interchangeable in these media. Arsenic is present every where in nature. Main source of arsenic is the volcanic rocks which transported to the plain land before dumping in sea by the river system from their upstreams originated in the mountains. By this process from the thousands of years during flow of water, these rocks become crushed by the stream of river.

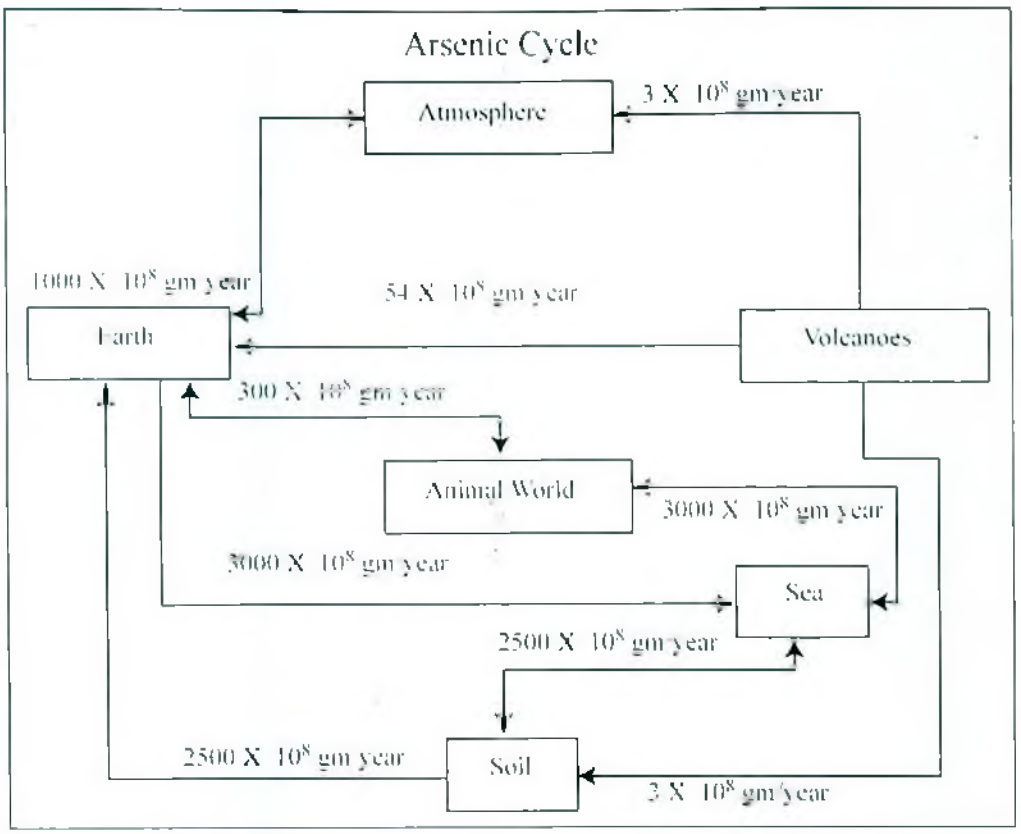


Figure-3.3. Arsenic Cycle
Source : Ahmad, S.K., 2000

Extremely high arsenic concentrations of 4600 mg/kg have been reported in the arsenic horizon of soils near mineralized veins in British Columbia, Canada. Soils in areas surrounding geothermal activity contain such high concentrations of arsenic that the health of grazing animals is seriously affected. Seleniferous soils of South Dakota in the US Great Plains have arsenic concentrations from 7 to 8 mg/kg. The plants growing on these soils showed arsenic concentrations from 1 to 4 mg/kg fresh weight (Islam 1999). Under reducing conditions, arsenic dominates in soils, but elemental arsenic can also be present. Arsenic would be present in well-drained soils as arsenite ($H_2AsO_4^{1-}$) if the soil is acid or as arsenates ($H_2AsO_4^{2-}$) if the soil is

alkaline. Typical amounts of arsenic in natural uncontaminated soils varied from 5 to 6 mg/kg in Austria and up to 11 mg/kg in the Netherlands and Canada. However, variation among soils can be great certain chilean soils had 21 to 231 mg/kg arsenic. Some regional changes in arsenic have been found related to soil moisture. Soils derived from shales and granites have been shown to have elevated arsenic concentrations of up to 25 mg/kg and Australian soils derived from quertzite have 100 to 200 mg/kg, resulting in reduced growth and toxicity symptoms on leaves of Bannana plants. Along the Eastern Australian coast, "acid-sulphate" soils have been mapped in deltaic and estuarine sediments of Holocene age. These soils contain iron sulphides, especially pyrite (FeS_2), which oxidise and form sulphuric acid when they are drained or disturbed by land and reclamation. The pyretic soils originally formed in vegetated tidal environments such as mangrove swamps (WHO, 2001).

Soils to which cacodylic acid (Hydroxydimethyl arsine oxide) was added showed that arsenic was extensively (60 per cent) volatilized under anaerobic conditions, but only 35 per cent was lost under aerobic conditions. Soil contains 4 mg/kg of arsenic with an average background level of about 7 mg/kg (Nair et al., 2003).

Arsenic occurs naturally in the soil. It is extremely prevalent in the landmass of the Ganges-Brahmaputra-Meghna (GBM) basin as well as in parts of Sylhet basin.

Arsenic from weathered rock and soil may be transported by wind or water erosion. However, because many arsenic compounds tend to absorb to soils, leaching usually results in transportation over only short distance in soil

(Welch et al., 1988). However, rainwater or snowmelt may leach soluble forms into surface water or groundwater, and soil microorganisms may reduce a smell amount to volatile forms (arsines) (WHO, 2001).

Oxidation, reduction, adsorption, dissolution, precipitation and volatization of arsenic reactions commonly occur in soil. In the pore water of aerobic soils arsenate is the dominant arsenic species, with small quantities of arsenite and MMA in mineralized areas.

The amount of arsenic sorbed from solution increases as the free iron oxide, magnesium oxide, aluminum oxide or clay content of the soil increases; removal of amorphous iron or aluminum components by treatment with oxalate eliminates or appreciably reduces the arsenic sorption capacity of the soil. Barry et al (1995) examined the adsorption characteristics of a forest soil profile. The greatest sorption capacity for arsenic occurred at a depth of 30 cm in the profile, in the B2 horizon where there was a predominance of clay and oxydydroxides of iron and aluminium. Adsorption of arsenic on soil colloids depends on the adsorption capacity and behaviour of these colloids (clay, oxides or hydroxides of aluminium, iron and manganese, calcium carbonates or organic matter). In general, iron oxides/hydroxides are the most commonly involved in adsorption of arsenic in both acidic and alkaline soils. Manning and Goldberg (1997) studied the adsorption of arsenic in three arid zone soils. They found that the soil with the highest citrate-dithionite extractable iron and percentage of clay had the highest affinity for arsenite and arsenate and displayed adsorption behaviour similar to that of pure ferric oxide. Adsorption isotherms indicated that arsenate species adsorbed more strongly than arsenite.

The surfaces of aluminium oxides/hydroxides and clay may play a role in arsenic adsorption, but only in acidic soils. Carbonate minerals are expected to adsorb in calcareous soils, Goldberg and Glaubig (1988) concluded that carbonates play a major role in arsenate adsorption at pH> 9. Phosphate substantially suppresses arsenate adsorption by soil, with the extent of the suppression varying from soil to soil. Roy et al. (1996) found that the adsorption of arsenate was significantly reduced by competitive interactions with phosphate in three different soil types (clay, silt loam and ultisol). Darland and Inskeep (1997) found that phosphate effectively competed with arsenate for adsorption sites on sand in batch isotherms as well as in saturated transport studies. The phosphate competition was not, however, sufficient to desorb all of the applied arsenate either in simultaneously applied pulses, or in a column where arsenate was applied before a concentrated pulse of phosphate. Approximately 40 per cent of the applied arsenate remained sorbed to the sand even after the total phosphate loading exceeded the column capacity by more than two orders of magnitude. The authors concluded that rates of arsenate desorption play an important role in transport of arsenate through porous media. Elkhatib et al. (1984) found that arsenite adsorption was not reversible, with only small amounts of sorbed arsenite released during subsequent desorption procedures. No significant correlation was found between arsenic adsorption and soil organic carbon or cation exchange capacity (CEC).

Jones et al. (1997) found that increased mobility of arsenic after liming appears to be consistent with the pH dependence of sorption reactions of arsenic on iron oxide minerals rather than dissolution-precipitation reactions of solid metal arsenates.

Sakata (1987) reports distribution coefficients (K_4) for arsenite for 15 subsurface soils from different sites in Japan with K_4 values ranging from 75 to 1200. The distribution coefficient was significantly correlated with the extractable iron content of the soils.

Precipitation is another mechanism of arsenic removal from soil. Thermodynamic calculations showed that in acidic oxic and suboxic soils, iron arsenate may control arsenic solubility, whereas in anoxic soils, sulfides of arsenite may control the concentrations of the dissolved arsenic in soil solutions. In alkaline, acidic, oxic and suboxic soils, precipation of both iron arsenate and calcium arsenate may limite arsenic concentrations in soil solutions. Carey et al. (1996) studied the sorption of arsenic in two free-draining sandy soils in New Zealand. They concluded that arsenate sorption occurred primarily through adsorption rather than a precipitation mechanism.

Many soil organisms are capable of converting arsenate and arsenite to several reduced forms, largely methylated arsines which are volatile. It was proposed that about 12 per cent of the arsenic applied and present in a soil is lost through volatilization of alkylarsines each year. Woolson and Isensee (1981) report total losses of 14-15 per cent per year from soil treated with sodium arsenite, DMA or MMA. Most of the loss was through volatilisation, although some apparent loss was caused by movement to or mixing with subsoil. Sandberg and Allen (1975) estimated an arsenic loss of 17-35 per cent per year through volatization. Sanford and Klein (1988) report that arsenic volatilization showed a direct relationship with nutrient levels and microbial growth in soil.

Leaching does not appear to be a significant route of arsenic loss from soil. Arsenic as MMA was applied to three soil types over a 6 year period. Percentage recovery of applied arsenic averaged 67 per cent, 57 per cent and 39 per cent in a fine sandy loam, a silt loam and a sandy loam soil respectively. All of the arsenic recovered in the soils was detected in the ploughed layer (< 30 cm) with no evidence of leaching into deeper zones. Elfving et al. (1994) monitored the movement of arsenic following the application of lead arsenate to fruit orchards for insect control. The rate of decrease in concentration of arsenic with depth was significantly greater in a sandy soil than in clay, suggesting that downward movement occurred less readily in the former. It was studied the vertical distribution of arsenic in six contaminated orchard soils. Most of the arsenic was restricted to the upper 40 cm, with maximum arsenic concentrations ranging from 57.8 to 36.3 per cent mg/kg. Absolute soil enrichment with arsenic occurred to depths between 45 and > 120 cm, with arsenic concentrations of 5.3 - 47.3 mg/kg and 120cm. The authors state that the deeper movement found in this study compared with many others is due to high loading rates of lead arsenate, coarse soil texture, low organic matter content and use of irrigation. The use of phosphate fertilizers significantly increases the amount of arsenic leached from soil contaminated with lead arsenate pesticide residues.

It was found that at soil Eh levels of 200 and 500 mV arsenic solubility was low and the major part (65-98 per cent) of the arsenic in solution was arsenate. Under moderately reduced soil conditions (at 0 and –100 mV) arsenic solubility was controlled by the dissolution of iron oxyhydroxides. Arsenic was co-precipitated as arsenate with iron oxyhydroxides and released on solubilization. On reduction to –200 mV the soluble arsenic

content increased to 13 times what it was at 500 mV.

Richardson et al. (1978) monitored surface runoff of arsenic from a fine montmorillonitic clay after application of arsenic acid for desiccation of cotton (*Gassypium hirsutum*). They calculated that approximately 7 per cent of the amount applied would be transported from the watershed by runoff and erosion, 38 per cent in solution and 62 per cent attached to sediment.

It was calculated an average half-life of 6.5 = 0.4 years for arsenic persistence on two Netherlands soils after application of arsenite.

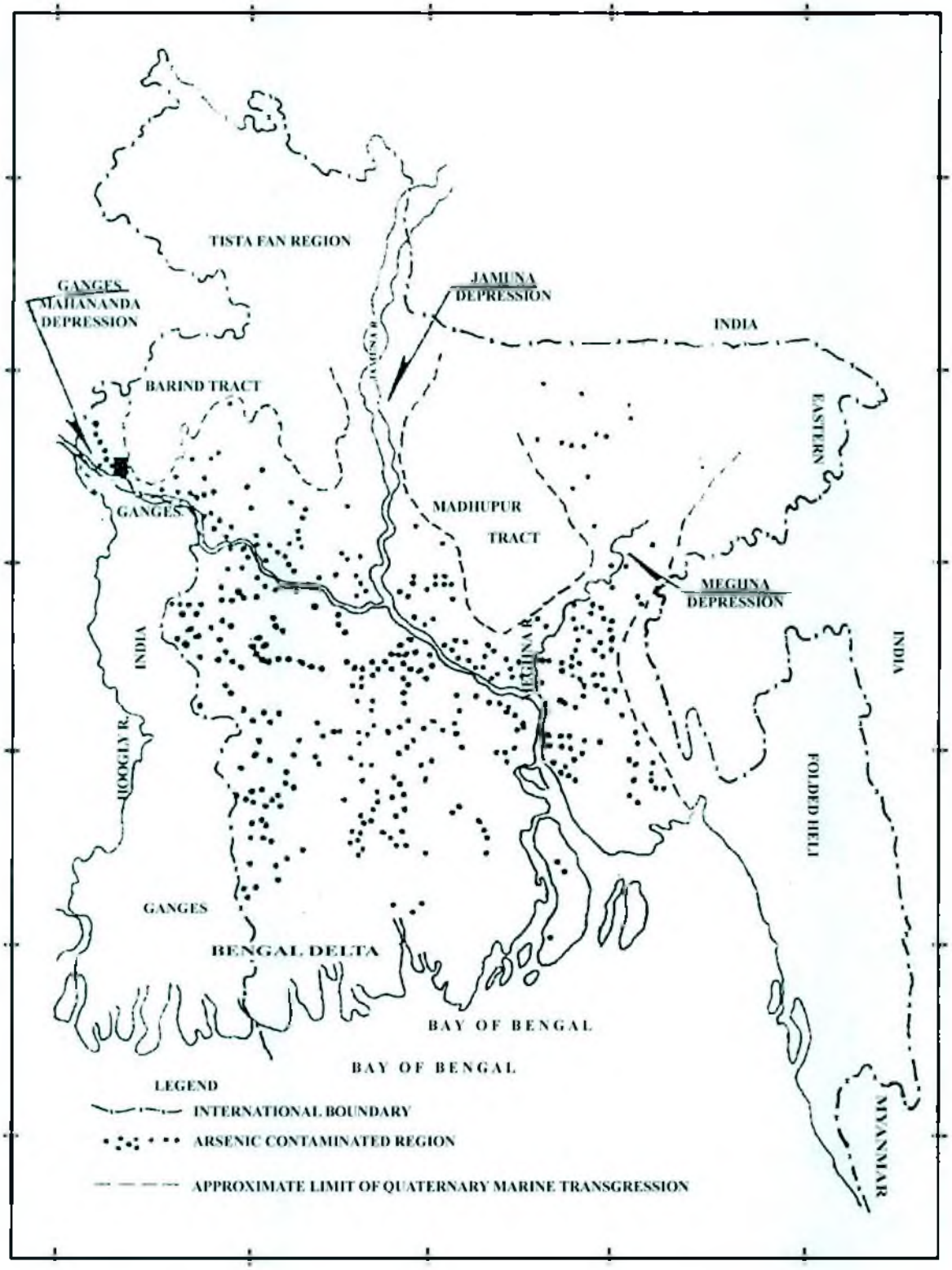
3.8. Arsenic in Bengal Delta:

Bangladesh occupies the major portion of the Bengal basin. Nearly 85 per cent of the recent sediments of Bangladesh have been deposited by alluvial and deltaic processes of the mighty rivers like the Ganges, the Brahmaputra, the Meghna and the Teesta. The Bengal Delta plains is characterized by a thick succession of fluviatile sediments pertaining to Quaternary age. The arseniferous belts located in the Upper Delta Plains (UDP) are mostly characterized by complete or truncated cycles of fining upward sequences dominated by course to medium sand, silt and clay sediments (Bhattacharya et al., 1998). Arsenic contaminated drinking water in the Ganges delta of Bangladesh is now recognized as one of the world's largest environmental health problems. The problem of arsenic contamination in groundwater in the vast tract of alluvial aquifers in Bengal Delta Plain is a subject of global concern and known to have affected a population of about 38 million in West Bengal another 40 million in different districts of Bangladesh (ACIC, 1998). Azizian et al., (2002) discloses that the arsenic problem now facing the Bangladeshi people in the Ganges and Brahmaputra delta regions. In

1999 Miah, M.A. University of Arkansas, U.S.A. reported that prior to the 1970 hundreds of thousands of people in 2800 villages of Ganges Delta drink water from 280,000 hand-dug well (Bridge and Husain, 2000).

The map of arsenic contaminated region (Map 3.2) shows that high contaminated areas are found in the catchments of the Ganges, Brahmaputra and Meghna rivers. This finding has suggested by Bridge and Husain (2000) and they have strongly suggests that there were multiple sources of arsenic in the above mentioned areas.

Regarding geomorphological units, the most arsenic contaminated ground water is found beneath the Meghna River Floodplain and Meghna Estuarine Floodplain. The types of sediment deposited in the delta region have been strongly influenced by global changes in sea level during the pleistocene glaciations. For example, "sea level was more than 100m lower at the peak of the last Ice Age around 18,000 years ago. At that time the major rivers cut deeply incised valley into the soft sediments of the delta. All of the highly contaminated groundwater occur in sediments deposited since that time, while those sediments predating the low sea level stand contain little or no arsenic contaminated groundwater" (Bridge and Husain, 2000). Arsenic is only found in groundwater drawn from the Holocene Ganges and Brahmaputra alluvial sediments whereas, older sediments, outer-opping as the Madhupur and Barind Tracts in central and north western regions contain arsenic free groundwater (Nickson, 1997).



Map-3.2: Arsenic Contaminated Region in the Bengal Delta.

Source: Bridge and Husain, 2000

The Ganges-Padma, the Brahmaputra-Jamuna and the Meghna river systems drain a huge areas of land outside the territory of Bangladesh carry 2.4 billion tons of sediments, a part of which is deposited in the flood plains each year. The average arsenic concentrations of sediments from the river Ganges, Brahmaputra and Meghna are 2.0, 2.8 and 3.5 mg/kg respectably, while arsenic concentration in river water is less than 3 μg/l (Ahamed. 2002). The Ganges-Brahmaputra-Meghna (GBM) has been extablished that the "younger ridge", the geological stretch of land which is relatively young – less than 10,000 years old– are particularly prone to arsenic contamination. But older than areas are also showing up on the contaminated map leading to the theory that the water that has washed the delta for thousands of years is highly arsenic laden and wherever that water has gone, the land has been affected.

Both the arsenic content of Bangladesh sediments (0.4-10 mg kg^{-1}) and their mineralogy are typical of young alluvial and deltaic sediments that contain a wide variety of minerals reflecting their diverse source rocks. There is no need to speculate on a unique geological source of high arsenic rocks somewhere upstream of Bangladesh.

Shahnewaz (1999) reveals that several hypotheses have been put forwarded to explain the release mechanism of arsenic in ground water of the Bengal Basin. The early hypotheses included anthropogenic sources such as agrochemicals, industrial wastes and wooden electric poles. According to the pyrite oxidation hypothesis, arsenic is released to groundwater due to oxidation of pyrite/arsenopyrite contained as pocket deposits in the aquifer sounds (Ahmed, 2000).

The SOES (School of Environmental Studies, Jadavpur University, India) has proposed that in West Bengal arsenic is released by oxidation of arsenopyrite present in the sediments and the oxidation is caused by an ingress of oxygen due to lowering of the water table over the last decades, SOES has suggested the some mechanism for Bangladesh.

The iron oxyhydroxide hypothesis presented at the 1998 conference (Ahmed et al.. 1988; Ravenscroft & Ahmed, 1998) and published later on (Nickson et al., 1998; Nickson et al., 2000, Ahmed, K.M. 2003) explains the possible source, transportation and released mechanism of arsenic in the Bengal Basin. This is controlled by the sedimentation history of the basin and can be conceptualized as shown in Figure 3.5.

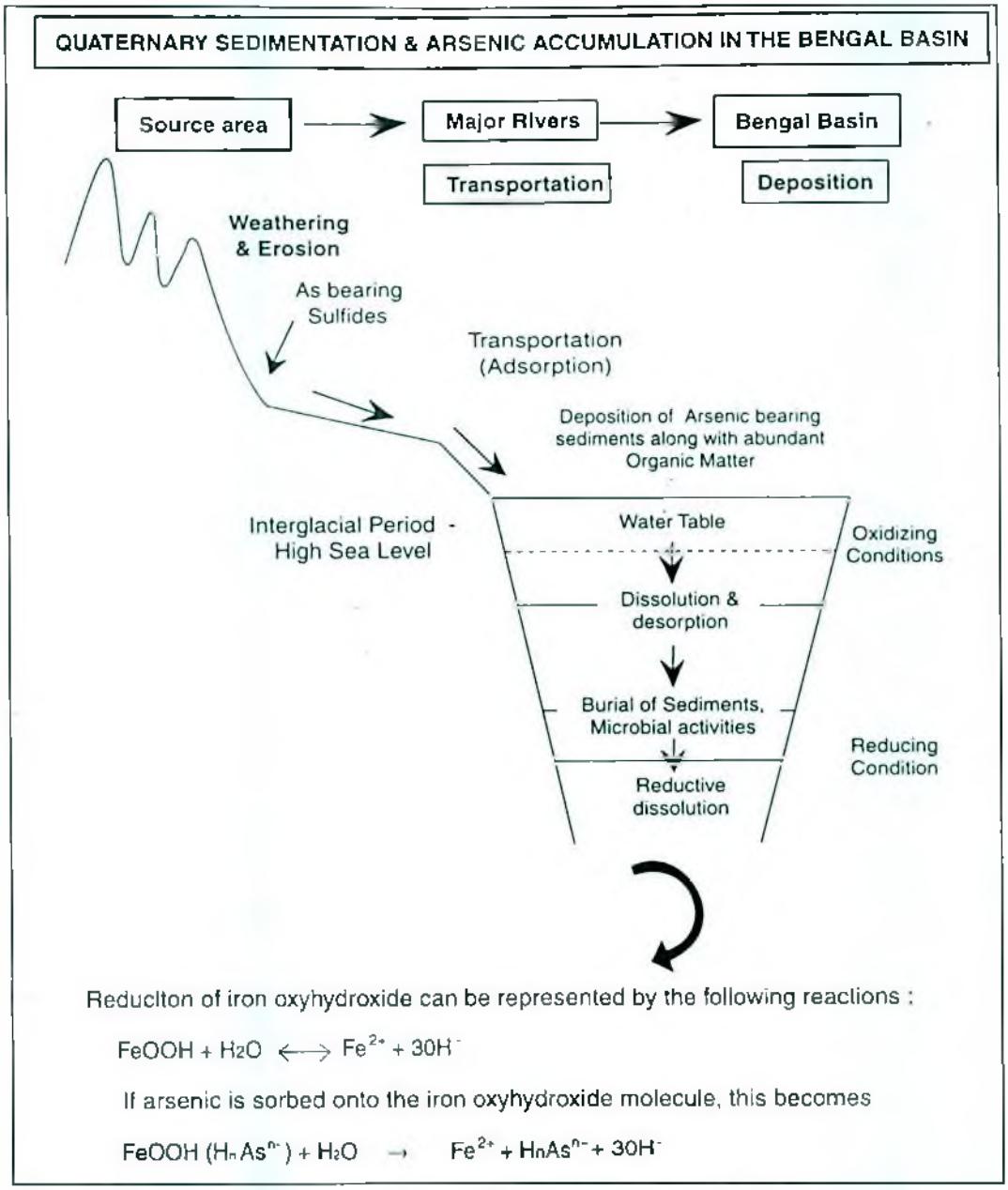


Figure-3.5: Source, Transportation and Release of Arsenic in Bangladesh
Source: Ahmed, 2000

3.9. Geochemistry and Hydrochemistry of Arsenic:

Arsenic is a poison omnipresent inside the earth. Arsenic that comes to the surface through exploitation of nature such as agricultural irrigation, withdrawing underground water, geothermal power plants or mining, has seriously contaminated the environment. According to the era genesis,

arsenic originates as a hypothermal deposit which is said to hydrothermal deposit formed at great depth and in the temperature of 300° - 500°C (Khan, and Ahmed, 2002)

Geochemistry of arsenic is mostly of Ca(Mg) HCO_3^- type with few $NaHCO_3^-$ type and rarely Nacl type. The dissociation of As (III) and As (V) acids is quite different and can be quantified by the equilibrium constants of dissociation (pKa, i).

$H_3AsO_4 \leftrightarrow H_2AsO_4^- + H^+$; pKa,1 = 2.19

$H_2AsO_4^- \leftrightarrow HAsO_4^{2-} + H^+$; pKa,2 = 6.94

$HAsO_4^{2-} \leftrightarrow AsO_4^{3-} + H^+$; pKa,3 = 11.5

$H_3AsO_3 \leftrightarrow H_2AsO_3^- + H^+$; pKa,1 = 9.20

Others are not known.

The redox reaction of the As(III)/As(V) system can be described effectively by the following equation.

$H_3AsO_4 + 2H^+ + 2e^- \rightarrow H_3AsO_3 + H_2O$, $E^o = +0.56V$

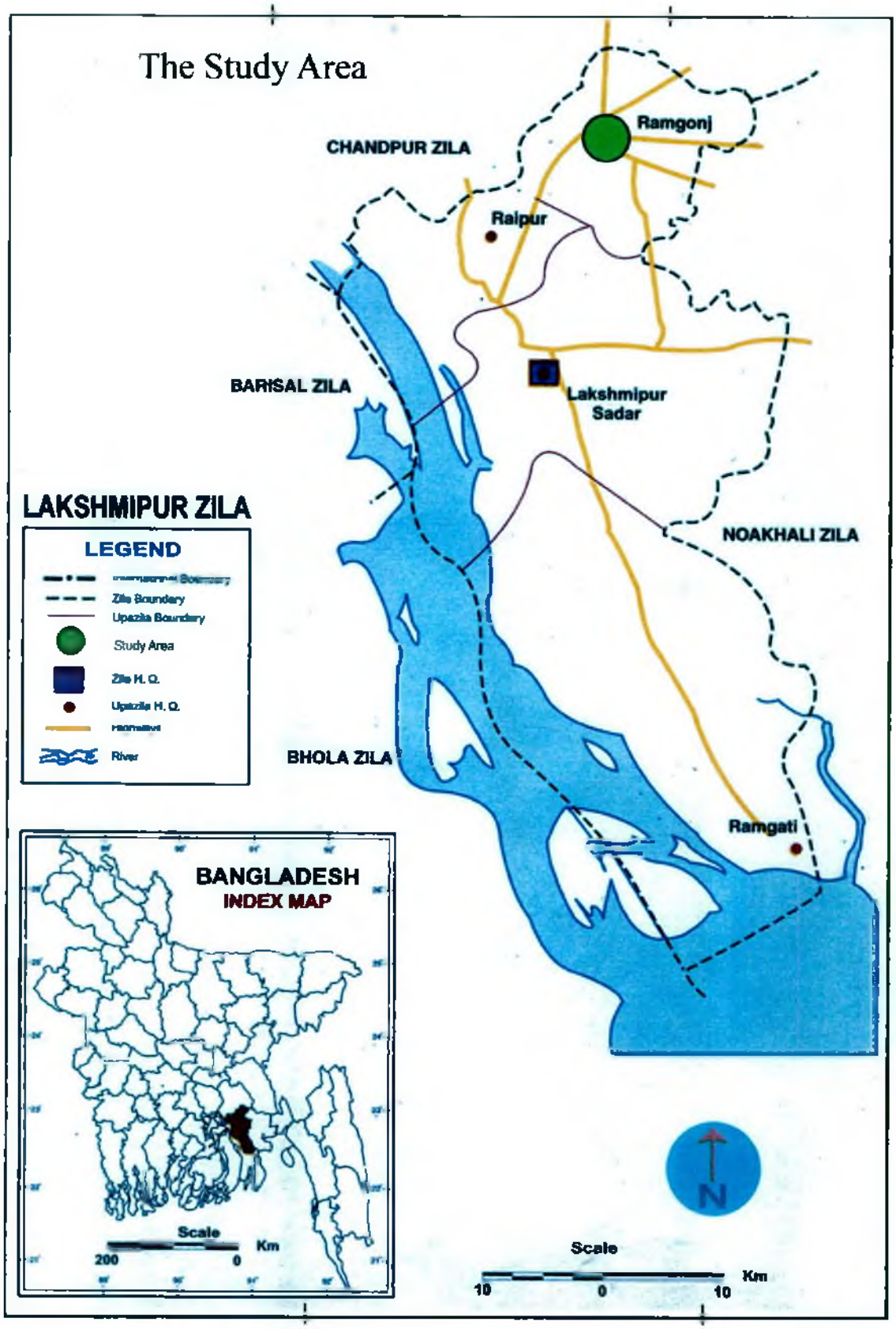
Hydrogeologically arsenic contamination occurs within the unconfined shallow aquifers, which occur within a few meters from the ground surface. Most of the hand tube wells abstract water from this aquifer.

CHAPTER FOUR

4. STUDY AREA:

4.1. Introduction:

Bangladesh is facing the largest mass poisoning in the history of mankind in the arsenic poisoning in groundwater. There is a distinct geographical distribution of arsenic with the greatest concentrations in the south and southeast and the smallest concentrations in the north and northwest of Bangladesh. About 57 million people of Bangladesh are drinking water from shallow tubewells that contains harmful concentrations of arsenic. The groundwater of Bangladesh particularly drawn from shallow aquifers has been found to be contaminated with arsenic and some areas in Ramganj Upazila of Lakshmipur District has been identified as a highly affected area. Under the research, investigation on the problem was made in the village of Auguankhil, Abhirampur, Chandipur, Panpara, Rasulpur, Quashimpur, Bazar, Tamta, Angarpara and Rudrarampur of this upazila. For an understanding of the problem, a test geological hole was drilled, detailed log has been prepared, sediment have been sampled for laboratory analyses. Before the test drilling, field trip was made to test the water from tubewells with arsenic field test kit and also measured some other parameters and collected water samples for laboratory analyses. During the drilling, field partisans tested water of earlier selected tubewells to observe variation.



Map-4.1: Location Map of the Study Area

4.2. Location of the Study Area:

The studied area is located under the Ramganj Upazilla of Lakhsmipur District of Bangladesh. And lies between latitude 23° 05′ 0″ N and 23° 15′ 0″ N and longitude 90° 45′ 0″ E to 91° 0′ 0″ E. The is on coded in the Survey of Bangladesh Topographic Sheet No. 79 I/16 in the scale of 1: 50,000 and site of the geological test drill hole is N 23° 5′ 48″ and longitude 90° 50′ 25″ E.

4.2.1. Extent of the Study Area:

The study area is bounded on the north by Shahrasti and Faridganj upazilas of Chandpur district on the east by Chatkhil upazila of Noakhali district on the south by Lakshmipur Sadar upazila and on the west by Raipur upazila and Faridganj upazila of Chandpur district. The study area is very close to the Meghna River.

4.2.2. Accessibility of the study area:

Sampling and field survey is an important part of any research. All the sampling and field surveys accomplised in the "Ramganj Upazila" were concentrated in the nearness of the "Upazila Head Quarter". The study area occupies an area of 69.31 sq. kilometre. The study area is well communicated with the Capital city Dhaka, Divisional city Chittagong as well as the district town Lakshmipur by means of national regional highway and the bus services are available from the mention places. The Upazila Head Quarter is a small township and accessible by metalled road from the ditrict head quarter and other places. Some of the villages close to the Upazila Head Quarter has got road connection. Most of the remote villages

of the Upazila is poor accessible. The village areas are characterized by high homestead levels next to low agricultural lands, but which are not flooded every year, on account of embankment. Lack of well road, through the villages make accessibility particularly difficult.

4.3. Physiography of the Study Area :

The area lies in the southern part of the Tippara Surface comprising the high flood plain geomorphic unit (Rashid, 1991) , and the Chandina Deltaic Plain (Bakr, 1979). The elevation of the ranges are from 3m to 4m above the mean sea level (a.m.s.l). The hole site lies in the polder area constructed by Bangladesh Water Development Board .

4.4. Soil of the Study Area :

The soil of the upazila has alluvial sediment of recent origin with admixture of sand and clay in varying proportion. It is lying in low parts of the Meghna estuarine floodplain, formed almost level alluvial land within the Meghna estuary. The soils on the south are slightly calcareous and some are saline in varying degree. In the north it has non-calcareous brown soil of the old Meghna estuarine floodplain.

4.5. Climate of the Study Area :

The upazila has a mild temperature and high humidity. The summer begins from April and continues till the middle of June. The monsoon commences from the end of June and continues till the middle of October. The dry winter starts from November and continues upto the end of February. The maximum and minimum mean temperatures during the winter vary from 27.1°C to 12.4°C. during summer, the maximum and minimum mean

temperature vary from 33.0°C to 25.5°C. The level of humidity is around 79 per cent in January and around 90 per cent in July. The annual rainfall of the zila recorded in 1996 was 2709 millimeters.

4.6. Vegetation of the Study Area:

Lakshmipur and its upazila Ramganj is the coastal area at the fringe of the Bay of Bengal with vast char land of recent origin in the South. The plant life if confined generally to variations belonging to the lower Gangetic plain and of other District in the southern region of the country. Except the Government sponsored afforestation program for the coastal belt there is no organized forestry in the district. However all homesteads are usually covered by dense and lush green foliage of wide variety of trees.

In the farmlands, varieties of crops namely local and HYV rice, jute, vegetables, spices, pulses, oilseeds, etc. are produced. Rice covers about majority percent of the gross temporary cropped area.

Most of the trees grown in homestead forests are fruit bearing. Mangoes, although poor in quality, grow in abundance. Almond or *badam* is unusually common. Other common trees are *Gab* (Diaspyros embryopteris), *Jam* (Eugenia jambolana), Plum, Tamarind or *tetul*, Jackfruit, Jalpai (Elaeocarpus serratius), wood apple or *bel* (aegle marmelos), *Chalta* (Dillenia indica), Boroi or *kul*, *Guava*, etc. *Banana* is seen almost everywhere but their quality is rather poor. *Litchi*, *Kamranga*, *Ata*, *Haritaki*, *Amloki*, etc. grow abundantly. Juice of *Gab* fruit mixed with charcoal is used in coloring boats and stiffening fishing nets.

Indigenous timber trees include *Koroi*, *Shal Koroi* (Albizia procera), *Garjan* (Dipterocarpus speciosa), *Jarul* (largerstroemia speciosa), *Shimul* (Salmalia),

etc. However, various exotic trees like *Teak, Mahagoni, Sissu*, etc. have been introduced as wayside trees as well as farm forestry. *Mandar* (Erythrina indica), a thorny tree mostly used as fuel and fencing, is seen in almost every household forest. *Shimul* and *Kadam* trees are very common and are preterred for manufacturing matchstick. The fruit or *Shimul or karpas* is used for stuffing mattresses and pillows and has a silky appearance. Newly introduced trees include *Eucalyptus and Pine.*

Mango wood is not good as a timber, but owing to its being in abundance, it is much used. The wood of Tamarind and *Kul* is hard grained and of good quality. The *Amaltas* is used for house and rough furniture. *Jarul* is used for boat building and pillars of house.

The luxuriant growth of palms is the most characteristic feature of the vegetation. *Supari* (Areca Catchu) plantations are more and more abundant towards the north and the west of the upazila and grows almost in forest. Cocoanut or *narikel* are grown abundantly throughout the upazila. Today palms or *Tal* (Borassus flabelliformis) and Date palms or *Khejur* are also very common. Date palm is a valuable tree. The juice is extractred and made into *gur*, the leave are made into mat. *Tal* wood is used for posts of houses and other building purposes, leaves are used for making large fans. *Supari and Narikel* are good source of household income.

Shady trees include Banyan or *bat* (Ficus indica), *Pipal* (Ficus religiosa) and *Nim* (Azadirachta indica). There are several varieties of canes, a good deal of bamboo of different varieties and thatching grass or *chhan* although their plantations are gradually decreasing steadily. Use of bamboo is widespread such as post and fencing of houses, making of baskets and trays of various

kinds. *Bet* is used for making baskets, binding and thatching. In the marshes are found *Sola* (Aeschynomene aspera Linn) and *Sitalpati* (Phryniumj dischotomum) which is extensively use making various types of mats and baskets.

4.7. Fauna of the Study Area:

Owing to the absence of organized forest and other natural conditions, any kind of large or medium carmivora are no longer seen in the district as well as Ramganj upazila. However, the following mammals are still seen the upazila although their number is gradually decreasing: *Jackal* (Canis aurcasl, *Fox* (Vulpes bengalensis). Large Indian Civet or *Bagdas* (Viverra zibetha), Ottar or *Ud* (Lutra penpicillata), *Irrawaddy, Squirrel, Kat Biral* (Collosciurus pygerythrus), Bengal mongoose or *Beji* (herpestes auropunctatus), different kind of rats and several species of bats.

Almost all varieties of birds that are seen all over Bangladesh are also commonly seen in Ramganj. Raptorial birds include King Vulture or *Shakun* (Trogos calvus), Lanner Falcon or *Baj* (Falco biarmicous), Marsh Harrier or *Gochila* (Circus aeruginesus), Pariah Kile or *Cheel* (Milvus migrans), several species of stork like Pond Heron or *Kani Boga* (Ardeola grayii), Cattle Egret or *Go Boga* (Babulcus ibis) and Black Bittern or *Kala Boga* (Dupeter Plovicollis), crows and King Fisher, etc. Ducks are represented by a number of species including winter migrants like Greenleg goose (*Anser anser), Rajhans* (Anser indicus), the *Pitail* (Anas acuta) and some other domestic species. Water birds include the Little Cormorant or *Pankawri* (Phalacrocorax niger), Waterhen or *Dauk* (Amaurornis phonicurus), watercock or *kora* (Gallicrex cinera).

Many kinds of colourful and singing birds are seen in the upazila. These include the national birds Robin Magpie (Copsycus sanlaris), *Kokil* (Eudymamys scolapacea), Oriole or Halde Pakhi (Oriolus Xanthornus), Kingcrow or Finga (Dicrurns adsimilis, (*Myna* (Sturnus malabarica), *Shalik* (Acridotheres tristis), Redvented *Bulbul* (Pycnonotus cafer), *Tuntuni* (Orthtomus sutharus), *Shama* (C. malabaricus), *Sparrow* (Passer domesticus), *Flowerpecker* (Dicacum erythrochynchos), *Babui* (famous for artistic nest building on the branches of high palm trees), several species of *pheasants, quails, pigeons and doves.*

The reptiles include different species of snakes, lizards and tortoises. The snakes include different varieties of Cobra, *Urgabora, Dughdabora, Kuchiabora* and *Jinlabora,* all poisonous. The lizards include gecko, calotis, wall lizard and monitor lizard. There are amphibians like *toad, frogs and tree frogs.*

There are many species of sea and fresh water fish available in the district and Ramganj upazila. The list of the varieties is too long to find place in this volume. Although Lakshmipur is a coastal district but most of the supply comes from ponds and tanks, canals and low lying areas inundated by rain water. Popular varieties include the carp tribe (Cyprinidoes), *Ruhit* (Labeo ruhita), *Katal* (Catla buchanani), *Mrigel*)Cyrrhiria mrigala) and *Kalabaush* (Labeo calbasu), *Airh* (Mystusaur), *Tengra* (Macrones) of several types, *Magur* (Clarious magur), *Singi* (Saccobranchus fossilis) and *Koi* (Anabas scandens or climbing perch) are considered to be delicious. *Shol* (Channastisus), *Boal* (Wallagonia atru), *Gazar* (Channa marulius) and *Pabda* are available in abundance. Prawn, cry fish (*icha)* and crabs are also found *Muralla, Punti, Khoksha, Bain* and *Chela* are small fish and are found all over the district in abundance.

Exotic fishes like *grass carp* (Cteropharyagoden idellus), *Silver Carp* (Hypotholmichthys molitrix), *Telapia* (Tilapia mossumbicus), *Nilotica* (Oreochroms niloticus), etc. have also been introduced for commercial pisciculture in ponds and tanks.

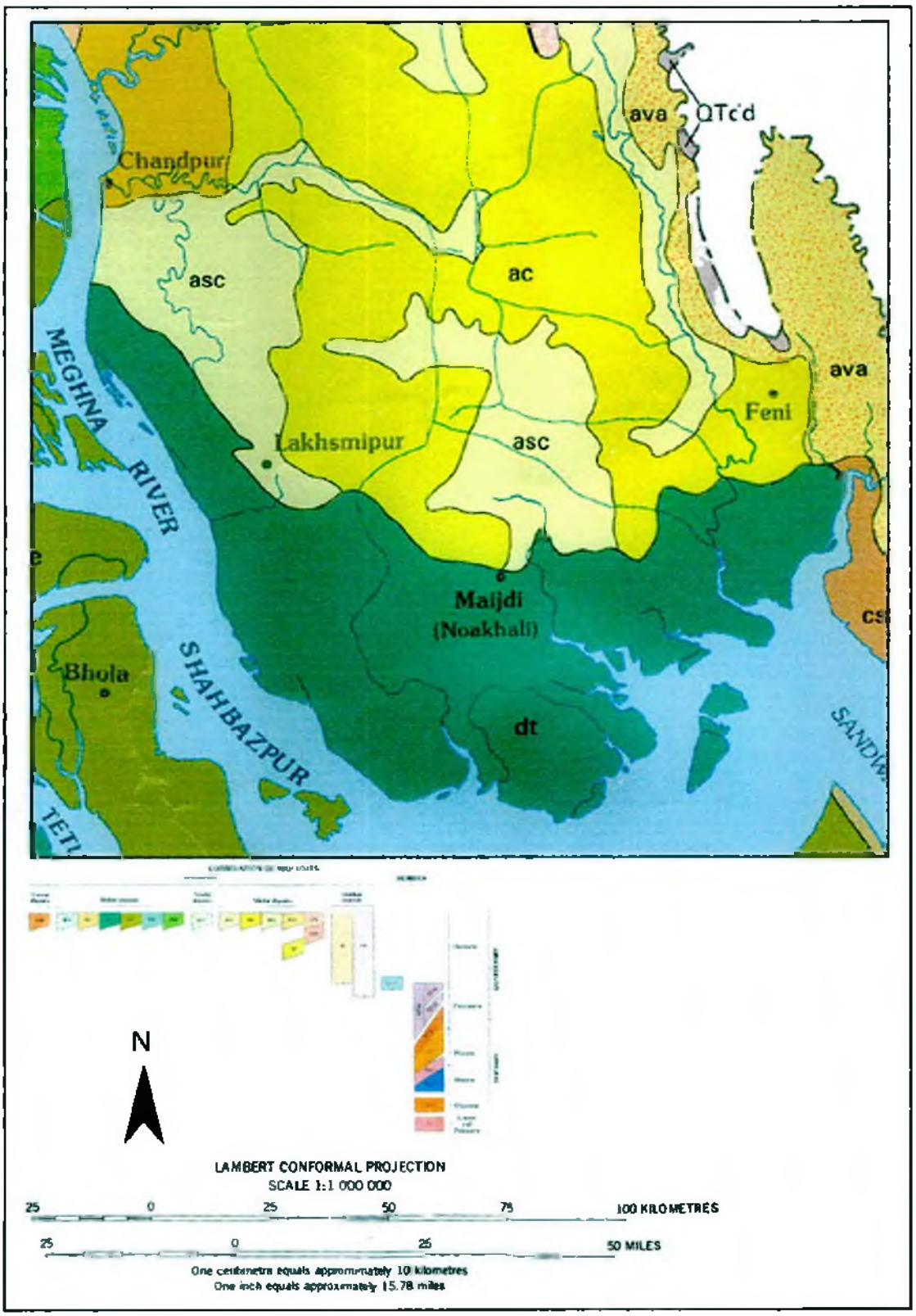
4.8. Geology of the Study Area:

Lakshmipur *upazila* is situated in the coastal belt of southeastern Bangladesh, close to the present course of the Meghna river system and downstream of its confluence with the Jamuna and Ganges rivers. The surface geology comprises in the south, alluvial silt and clay and tidal deltaic deposits which are part of the active Meghna flood plain, and in the north, Chandina Alluvium. The Chandina Alluvium is composed of yellow brown (partly oxidised) or grey silt and clay and is more consolidated, than the active floodplain sediments. The surface is elevated relative to the active floodplain and radiocarbon dating suggests that its deposition ceased during the middle Holocene (Alam et al., 1990). It was proposed a two-fold division of the Chandina Formation based on borehole records. They defined an upper unit, including ca. 3 m of surface clay (Chandina Alluvium), underlain by ca. 30 m of grey micaceous sand with occasional thin peat beds. Some boreholes from this horizon discharge methane (Ahmed et al., 1998). It was also described a lower unit of dark grey micaceous sandy silt containing brackish groundwater. These are underlain by further sandy deposits of unknown age.

In the southern part of the *upazila*, alluvial and deltaic sediments of the active Meghna floodplain are composed predominantly of inter-layered grey to yellowish-grey fine micaceous sand and grey clay and silt. Surface

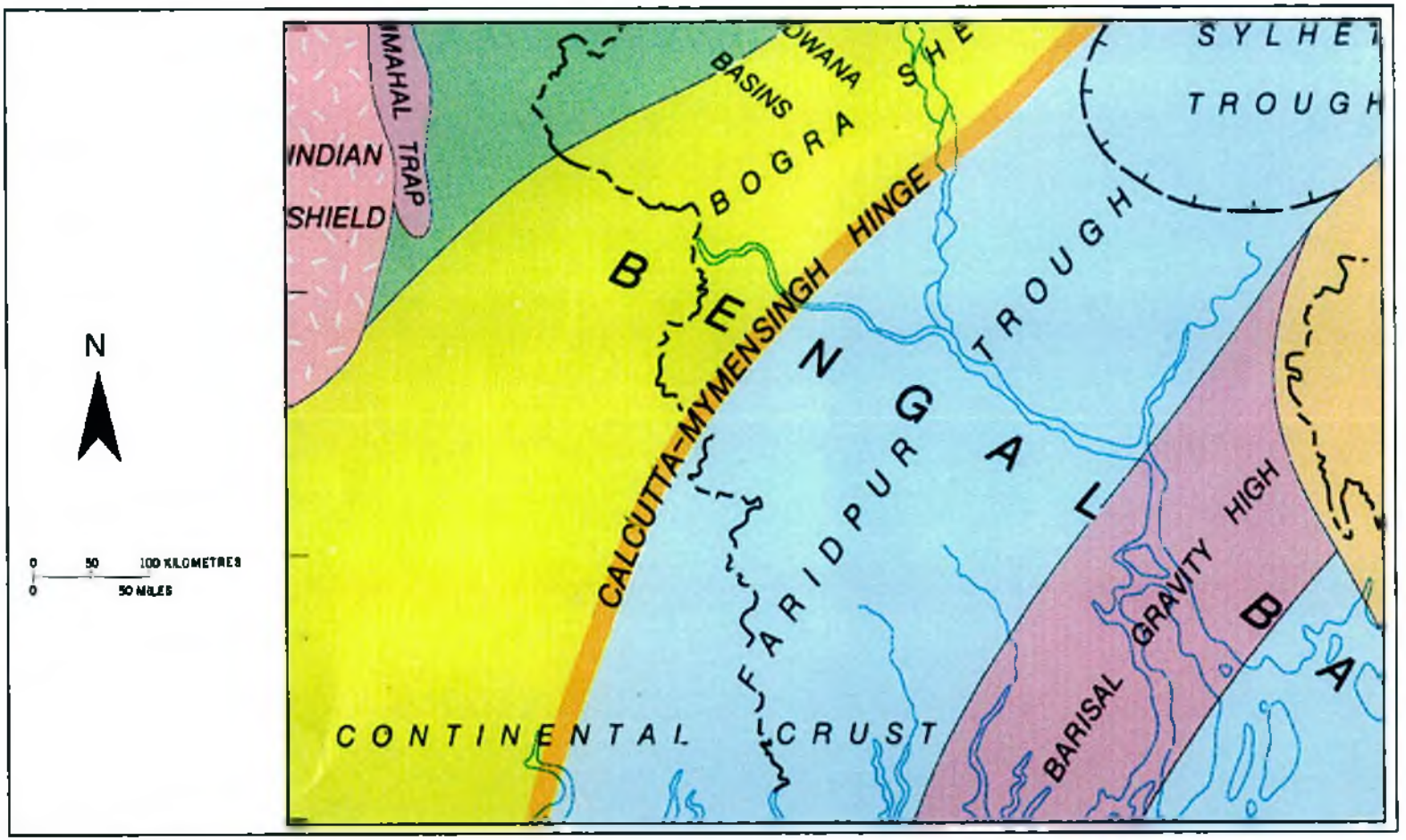
horizons are usually of silt or clay. Three main aquifer units have been described in the sequence: an upper unit extending down to about 80 m depth, a second unit between about 100 m and 130 m and a lower unit at greater than ca. 250 m, extending to ca. 350 m (DPHE/BGS/MMI., 1999). All are separated by clay and silt layers. The lower unit is believed to be the Dupi Tila Formation, but the stratigraphy at this depth has not been well-charactrerised. The subsurface relationship between the sediments of the active floodplain and the Chandina Formation is also not well understood.

Sediments recovered from the cored log of alluvial sediments at Lakshmipur reveal a large degree of vertical sediment heterogeneity, particularly at shallow depths (<60). Interbedded layers of silt and fine sand typically just a few centimeters thick occur in this interval and must give rise to considerable heterogeneity of groundwater flow on a local scale. Silts and fine sands (grey and brownish grey) predominate in the core profile down to around 85 m depth with a coarser sandy interval at 60-70 m. Radiocarbon analysis suggests that sediments down to around 70 m depth are generally around 10,000 years BP or less. Peat occurs at around 76-77 m depth (radiocarbon age >40,000 years BP). Between 85-150 m, sediments are more commonly grey medium and coarse sands. Below this, grey silts occur down to the base of the profile at 153 m. Radiocarbon data are difficult to interpret in the lower most part of the profile: sediments at around 80 m depth give radiocarbon ages of around 35,000-38,000 years BP whilst in the depth interval 92-138 m, the age dates (3 samples) are less than 13,000 BP. The profile does not penetrate as far as the deep aquifer used for groundwater abstraction and so age relationships of the deeper lithologies remain unknown.



Map-4.2: Geological Map Lakshmipur District and Adjoining Areas.

Source : Alam, M.K. et. al. 1990 (Ex-Director General, GSB)



Map-4.3: Generalized Tectonic Map of Bangladesh and Adjoining Areas

Source : Alam, M.K. et. al. 1990 (Ex-Director General, GSB)

Groundwater is abstracted from sandy sediments in the Chandina Formation and the alluvial/deltaic sequences of the active floodplain, as well as from the deep lower aquifer. Groundwater levels in both deep and shallow tubewells are generally shallow, just a metre or two below ground level. Groundwater quality is significantly impacted by salinity and the salinity variation with depth is complex (Jensenius and Rahman, 1997). However, abstraction is principally from two district depth ranges: <20 m and >170 m. Few tubewells abstract from the intermediate depth range because of the presence of brackish or saline groundwater in this interval. The depth of the groundwaters from the upper aquifer is shallower than in the other Special Study Areas. There is thus a large depth difference between the shallow and deep aquifers under investigation in Lakshmipur and there is unlikely to be hydraulic connection between the two.

4.8.1. Geological Setup:

The area under the study lies in the southern part of the Barisal Chandpur Gravity High and the corresponding Hatia Trough which has the thickest sediment coloumn of more than 30 km in the world (Guha, 1978). It is noted that the area lies in the southern of Barisal Gravity High (Rahman et al., 1990). The trough is greatly subsiding It is to note that are lies in between two deep drilling sites one in Begumganj Anticline and another in Muladi. Anticline in the west and Feni deep drilling site is very close to the area. All these geostructural features have impacts in the groundwater flow, recharge and storage.

4.8.2. Description Geological Cross Sections:

For an understanding of the extent and nature of the aquifers and aquifer materials two geological cross sections (GCS) have been made on the basis of the subsurface geology as encountered in the deep drilling in the Feni Anticline, Begumganj Anticline by the Petrobangla , bore holes done by the Bangladesh Water Development Board and the Project Drill Hole and privately owned tube well borings. Geological Cross section A-A/ represents geological log in the bore hole Comilla-91(BWDB), Augunkhil (PDH), Feni and Begumganj (Petrobangla) . The Geological Cross Section B-B / represents the geological logs at Comilla-91 (BWDB), Augunkhil (PDH), Rasulpur (TW) , Begumganj & Feni (Petrobangla). GCS A-A / shows that there are two aquifers nearby the Meghna river in the probable Holocene sediments which are being truncated in the east and runs in the east of Augunkhil. And at depth another aquifer is continuing in the east. It appears that this aquifer is the continuation of Dupi Tila Sandstone. In the section a thick aquitard is prevailing in between the area between Augunkhil and Begumganj and it shows virtualley very poor aquifer conditions. In the east of the section there prevailes a thick aquifer under a few mertres aquitard. This aquifer lithologically forms the Dupi Tila Sandstone that overlies the Girujan Clay. The GCS A-A / shows that there is good possibility deep aquifer in the area. The GCS B-B / depicts the similar condition. The Sonne Mission on the Bay of Bengal has found Toba Volcanic Ash beds (75,000 B.P) well preserved in the sediments in the Bay of Bengal and in the Indian Ocean. Toba Volcanic Ash might have contribution in the sediments that have been deposited after this great episode of volcanic activity.

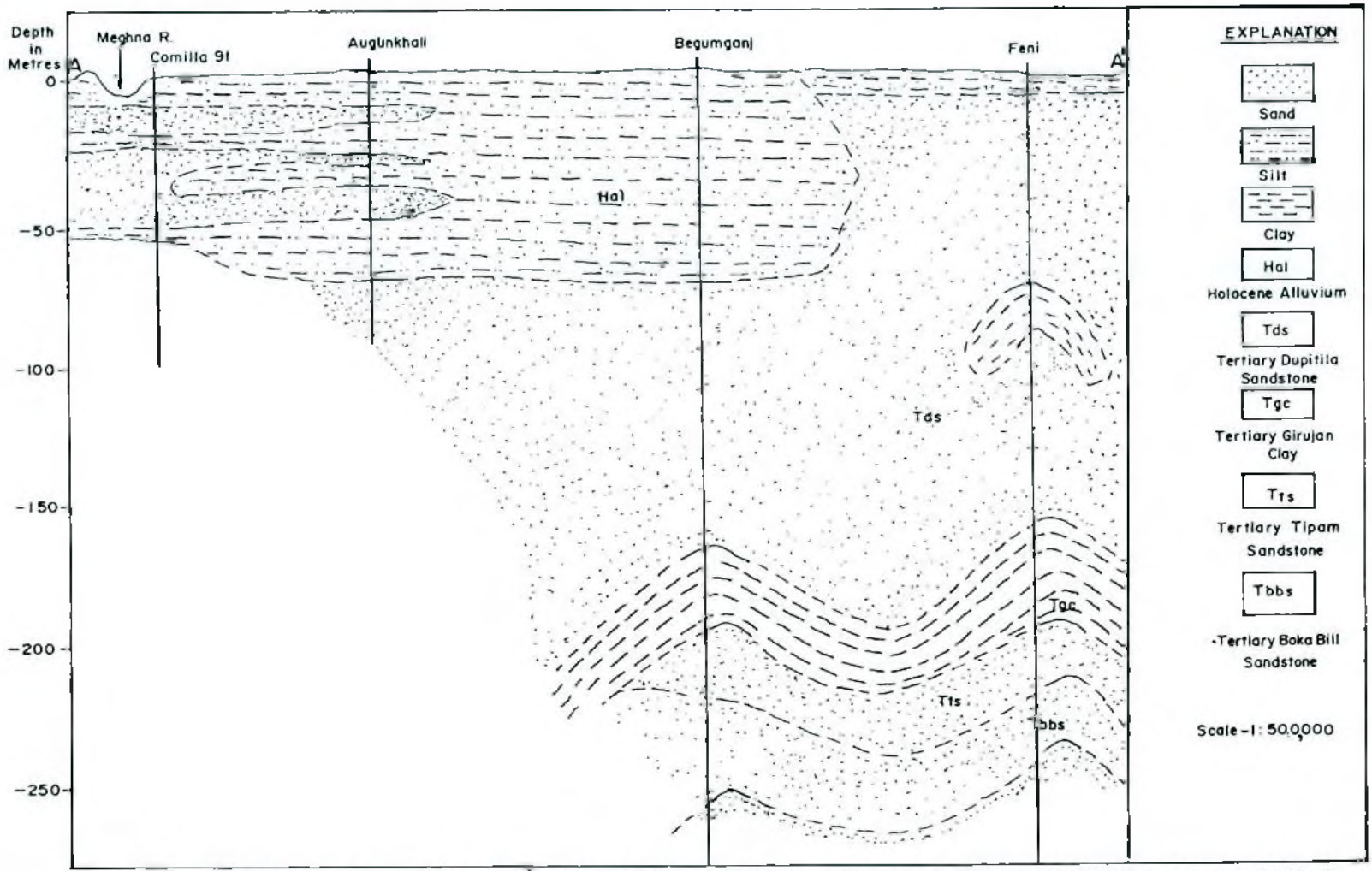


Figure- 4.1: Hydrogeological Cross Section A–A' constructed Based on Geological Logs at a. Comilla 91 (BWDB), b. Augunkhil (PDH), c. Begumganj (Petrobangla), d. Feni (Petrobangla).

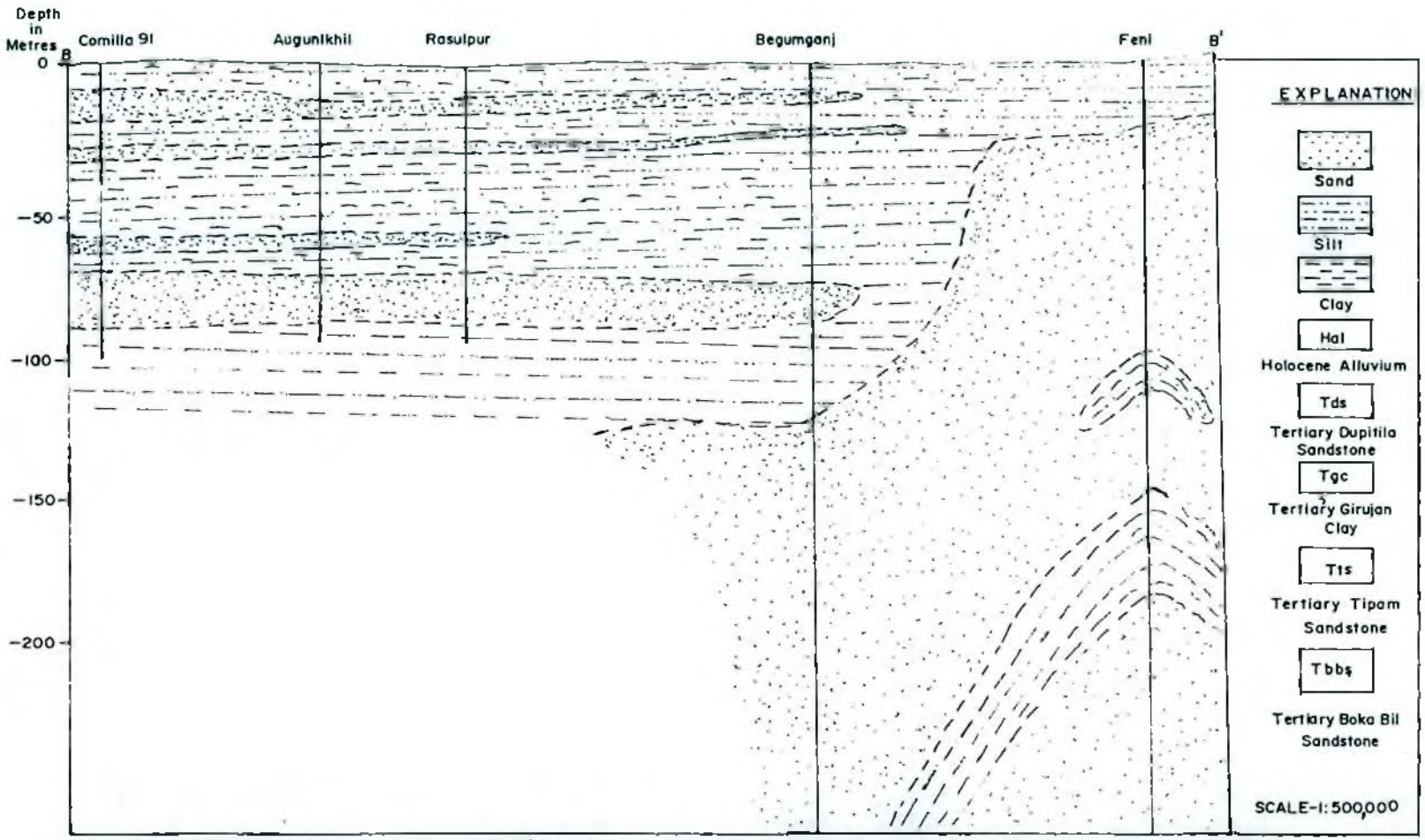


Figure- 4.2: Hydrogeological Cross Section B-B' constructed Based on Geological Logs at a. Comilla-91 (BWDB), b-Augunkhil (PDH), c.Rasulpur (TW), d.Begumganj (Petrobangla) and e.Feni (Petrobangla).

4.9. Lithology of the Study Area:

The obtained drilling data from the Begumganj Anticline shows that sediment coloumn ranging in age from Pliocene to Holocene is more than 700 in thickness. Groundwater resources are used to occur in this sediment coloumn. So far known, the groundwater in the shallow aquifer has been found to be contaminated with arsenic but the groundwater from the deep aquifer has been found to be safe drinking water. The geological data obtained from the test drill hole in Augankhil, data obtained in regards of shallow as well as deep tube wells and that from the deep drilling for hydrocarbon exploration, the generalized geological succession is as follows:

Table-4.1: Geological Succession in Ramganj Area, Lakshmipur District, Bangladesh

Formation	Lithological Lithology unit	Thickness in metres	Hydrogeo-logical	Age
Alluvium	i. Sandy silt, clayey sandy silt, silt, sandy clayey silt, grey, unconsolidated	10	Aquiclude	Holocene
	h. Sand, fine to medium grained, grey, unconsolidated	2	Aquifer	
	g. Sand, fine grained, clay silt, silt with micas, unconsolidated	2	Aquiclude	
	f. Sand, fine grained, unconsolidated	1	Aquifer	
	e.Sandy silty clay, micaceous with brown materials, unconsolidated	9	Aquiclude	
	d. Sand, fine to medium grained, dark grey micacious	2	Aquifer	to
	c. Sand very fine grained, silty clay, silty sand, micaceous, unconsolidated	30	Aquiclude	
	b. Sand, fine to medium grained, unconsolidated.	1.5	Aquifer	Late
	a. Silty clay, clay, unconsolidated	17.5	Aquiclude	Quaternary
---------- (Unconformity) ----------				
Dupi Tila	Sand grey, medium grained, Consolidated	15	Aquifer	Pliecone

Based : Based is not known

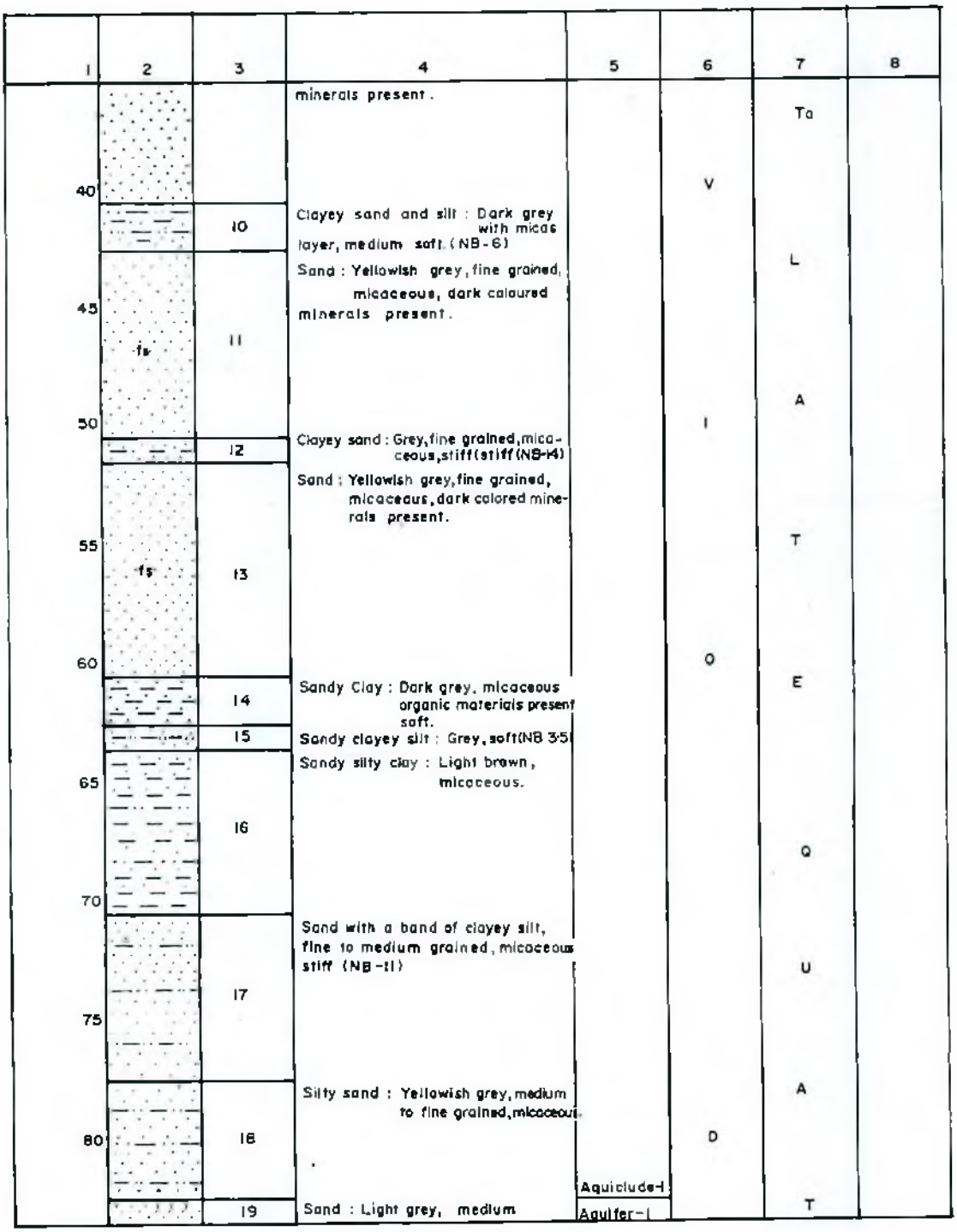
Ag/RG

DETAILED GEOLOGICAL LOG OF TEST HOLE DRILLED UNDER THE STUDY GROUNDWATER ARSENIC CONTAMINATION : GEO-ENVIRONMENTAL ANALYSIS

Village— Augankhali Upazila- Ramgang District-Lakhsmipur

Co-ordinate : Latitude N 23°5'37·2"—Longitude 90°50'15·5"E

Depth in M/Ft. 1	Lithologic section 2	Lithologic unit 3	Lithology 4	Hydrogeo. unit 5	Formation 6	Age 7	Comment 8
MSL		1	Sandy silt : Light yellowish grey, contains humous, soft.		F	H	
5		2	Clayey sandy silt : Grey to light yellowish grey, soft (NB-1-3).	Aquiclude-I			
		3	Sandy silt : Light yellowish grey, micaceous, soft.			O	
10		4	Silty sand : Light grey, very fine grained, micaceous soft		U	L	
15		5	Clayey silty sand : Light grey.			O	
		6	Clayey sandy silt : Light grey, very soft.		L		
20		7	Sandy clayey silt : Grey with patches of yellowish tints, dark minerals present.			C	
25						E	
30		8	Silty sand : Grey, fine grained, dark coloured minerals present stiff (NB-8).		U	N	
35	fs	9	Sand : Grey, fine grained, micaceous, dark coloured				



Depth M/Ft.	Lithologic section	Lithologic unit	Lithology	Hydrogeo unit	Formation	Age	Comment
90	ms	20	Sand : Grey medium grain.			A	
95	ms	21	Sand : Yellow, fine to medium grained, with micas, stiff (NB-13)		I		
100	fs/ms	22	Sand : Light yellow, fine to medium grained.	Aquiclude-1		T	
105	cs/ms	23	Sand : Grey, coarse to medium grained, grains are angular.	Aquifer-2		E	
100	cs	24	Sand : Grey, coarse grained, green, black and brick red coloured minerals present.			R	
115	cs/ms	25	Sand : Yellow, coarse to medium grained,		U	N	
120						A	
125							
130						R	
135	cs/ms	26	Sand : Light yellow, coarse to medium grained, stiff (NB-12).	Aquifer-2	M	Y	
			Unconformity				
140	fs	27	Sandstone : Pink, massive, fine grained stiff (NB-14).	Aquiclude	D	Pliocene	

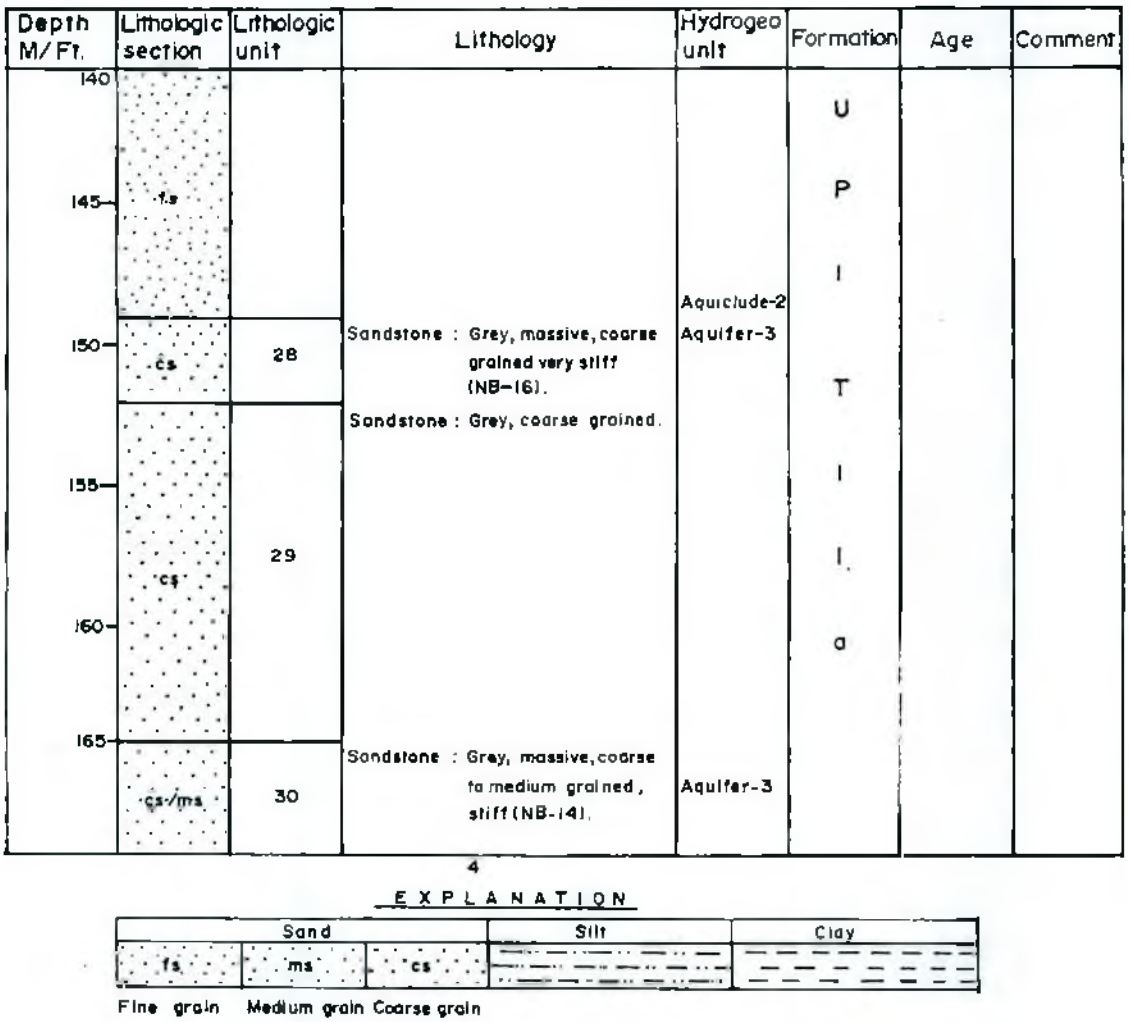


Figure-4.3 : Geological Log of Test Hole Drilled.

4.10. River System of the Study Area:

The rivers flowing through the zila and Ramganj upazila are the Meghna, the Dakatia, the Shabajpur and the Jasirdona. The widest Meghna, separates the Lakshmipur from Barisal zila. The Meghna and the Dakatia are navigable througbout the year. Total length of the rivers flowing over the zila is about 118 kms. With an area of about 322 sq.kms. Which is 22.65 per cent of total area of the zila.

4.11. Population of the Study Area:

The area of the study area is 169.31 sq. kilometer and it has a population of 238,333 of which 114.,363 are males and 123,970 are females. The sex ratio of the upazila is 92 males per 100 females as against 91 males per 100 females in 1981. The decadal population growth rate is 20.91 per cent and annual compounded growth rate is 1.92 per cent.

In the upazila, there are 43,995 households. In all, 13 of them are tribal households. Distribution of households by type shows that there are 98.39 per cent dwelling units, 0.26 per cent institutional units and 1.34 per cent other units.

The average household size for the upazila is 5.4 persons, for rural area the size is same i.e. 5.4 and for urban area the size is slightly big i.e. 5.6. The household size in dwelling, institutional and other units are 5.4, 4.2 and 1.8 persons respectively.

In the upazila, 91.44 per cent of the dwelling households use tubewell, 0.09 per cent use tap, 0.29 per cent use dug-well, 8.01 per cent use pond and 0.17 per cent use canal/river as main source of drinking water.

In Ramganj upazila, 10.81 per cent of dwelling households have sanitary latrines with 9.98 per cent in rural area and 20.24 per cent in urban area. A total of 80.04 per cent of the households have non-sanitary latrines with 82.06 per cent in rural area and 69.02 per cent in urban area. In this upazila, 9.15 per cent of the households have no toilet facilities.

Ramganj Municipality along with eight unions of the upazila have been brought under Rural Electrification Programme. So far, 4.13 per cent of the total households and 3.48 per cent of dwelling households reported to have electricity connection in the entire upazila.

In Ranganj upazila 67.44 per cent of the dwelling households own and 32.56 per cent do not own agricultural land. Percentage of ownership of agricultural land is 60.65 per cent in urban area as against 68.69 per cent in rural area.

In the upazila 41.15 per cent of the dwelling households depend on agriculture as the main source of household income with 23.06 per cent on cultivation/share cropping, 0.92 per cent on livestock, forestry and fishery, 0.08 per cent on pisciculture and 17.09 per cent as agricultural labour. Other sources of household income are non-agricultural labour (3.31 per cent), business (17.06 per cent) and employment (22.85 per cent). In urban area, main sources of household income are business (26.15 per cent), employment (20.67 per cent), non-agricultural labour (3.84 per cent) and agriculture (31.25 per cent).

The literacy is 45.0 per cent for both sexes, 49.2 per cent for male and 41.4 per cent for female. In case of urban area, it is 46.2 per cent for both sexes, 50.9 per cent for male and 41.4 per cent for female which are higher as

compared to the corresponding rates in rural area of 44.8 per cent for both sexes, 48.8 per cent for male and 41.4 per cent for female. In the upazila, the literacy is the highest i.e. 49.8 per cent in Darbeshpur union and the lowest i.e. 41.3 per cent in Bhadur union.

The child-woman ratio (Children 0-4/Women 15-49) per thousand for the upazila, rural and urban areas are 738, 747 and 688 respectively.

School attendance at the age group 5-24 for male is 56.5 per cent and for female is 44.8 per cent. This shows increases over the 1981 figures of 38.6 per cent and 23.8 per cent respectively.

In the upazila, 34.54 per cent of the population are below 10 years of age. Among the population of age 10 years and over 27.48 per cent are not working, 2.60 per cent are looking for work, 40.43 per cent are engaged in household work and the remaining 29.49 per cent are working. The distribution of working people shows agriculture (14.63 per cent), industry (0.46 per cent), water, gas & electricity (0.04 per cent), construction (0.58 per cent), transport and communication (0.89 per cent), business (5.52 per cent), services- self-employed (0.69 per cent) and others (6.67 per cent).

Urbanization: Ramganj Municipality is the only urban area of the upazila. It consists of 3 wards and 18 mahallahs and occupies an area 36.96 sq. km.

Table-4.2: Population and Other Variable at a Glance

Item	1991	1981	Growth Rate (%)	
			Decadal	Annual
1. AREA				
In sq.km.	169.31	169.31		
In sq.miles	65.37	65.37		
2.HOUSEHOLDS	43,995	36,871	19.32	1.78
Rural	36,941	33,897	8.98	0.86
Urban	7,054	2,974	137.19	9.02
3. HOUSEHOLD SIZE (Dwelling Unit)				
Thana	5.4	5.4	0.00	0.00
Rural	5.4	5.4	0.00	0.00
Urban	5.6	5.4	0.00	0.36
4. POPULATION	238,333	197,116	20.91	1.92
Male	114,363	93,982	21.69	1.98
Female	123,970	103,134	20.20	1.86
Rural	199,100	182,122	9.32	0.90
Male	94,542	86,211	9.67	0.93
Female	104,558	95,911	9.01	0.87
Urban	39,233	14,994	(+)161.66	10.10
Male	19,821	7,771	(+)155.06	9.82
Female	19,412	7,233	(+)168.75	10.39
5. DENSITY				
Per sq.km	1,408	1,164	20.96	1.92
Pre sq.mile	1,646	3,015	20.96	1.92
6. SEX RATION (m/f)				
Thana	92	91	1.10	0.11
Rural	90	90	0.00	0.00
Urban	102	108	(-)5.56	(-)0.57
7. LITERACY (7 Years and Over)				
Thana	45.0	37.0	21.49	1.97
Male	49.2	44.5	10.49	1.00
Female	41.4	30.5	35.60	3.09
8. SCHOOL ATTENDANCE (5 to 24 Years)				
Thana	55,428	28,869	92.00	6.74
Male	30,595	17,457	76.26	5.77
Female	24,833	11,421	117.60	8.09
9. URBAN POPULATION (%) 19.46	7.61	116.29	8.02	
10. GEOGRAPHIC UNIT				
Union	13	11		
Mauza	122	133		
Village	126	140		
Municipality	1	-		
Ward	3	-		
Mahalla		18		

Source: BBS, 1993

CHAPTER FIVE

5. METHODOLOGY

5.1. Introduction:

An environmental analysis is comprised of several steps. A well marked research or analysis requires the combination of the sampling and prepare for laboratory analysis, the field data and the existing data, previous data collection, field investigation, data organization and representation, interpretation and finally reporting on that particular study area. Sampling is the process by which we collect enough of a material to adequately represent the system which we wish to characterize. The sample should represent both the overall concentration of whatever substance is being measured, and the distribution of the substance in the system. Samples must be properly preserved. So that their compositions do not change before analysis. After the samples are taken, it must be prepared for analysis.

5.2. Method of Selection of Contaminated Tubewells :

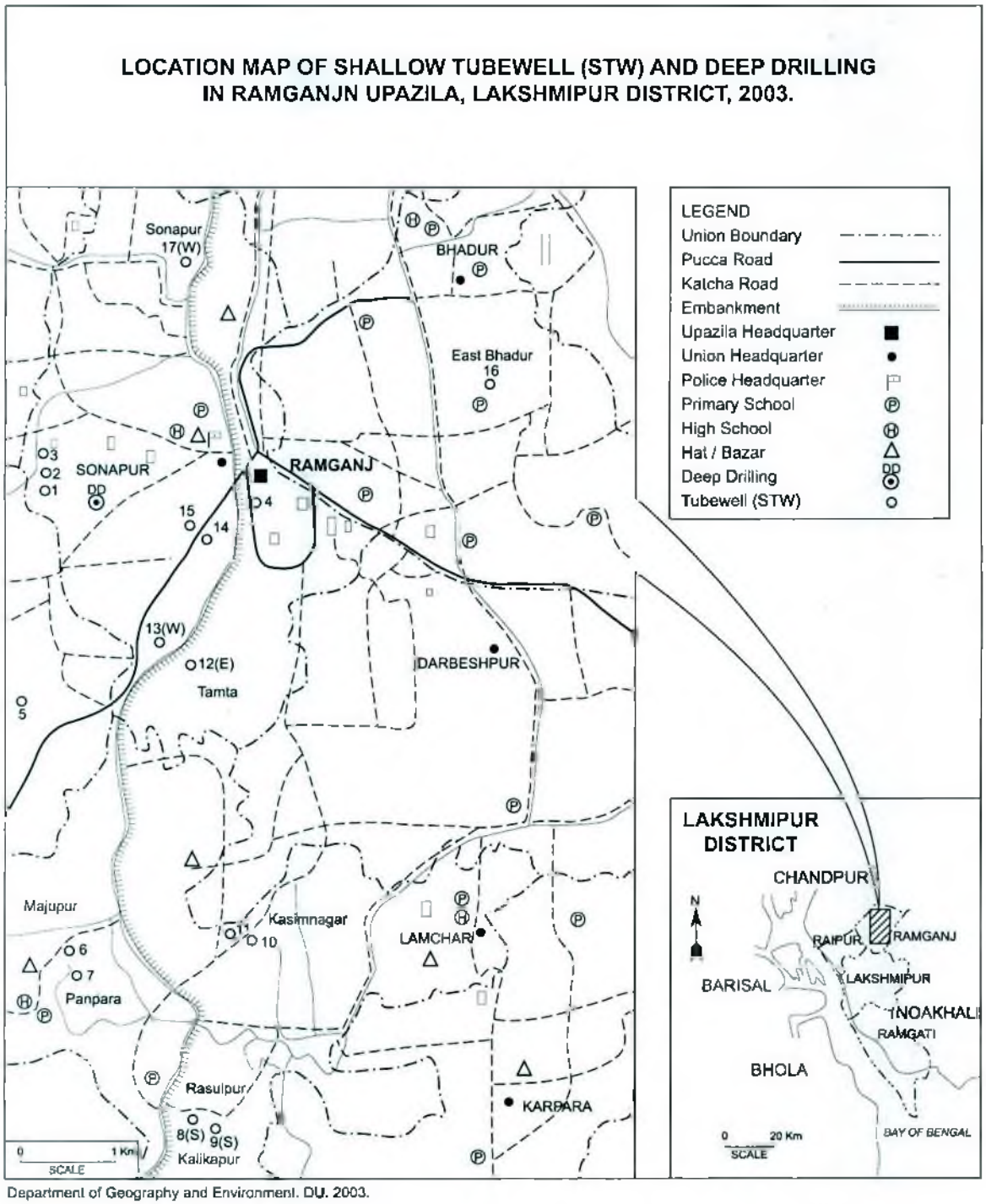
Arsenic in drinking water is the worst problem at Ramganj Upazila in Lakshmipur district of Bangladesh. According to the DPHE information more than 60 per cent Shallow Tubewells are affected by groundwater arsenic problem in this upazilla. A study has taken Ministry of Science and Technology in 2001, it has proved that more than 80 per cent Shallow Tubewells and 21 per cent people are clinically affected in this area (Bhuyian, 2001). Arsenic worst affected area, the study has taken the study upazila.

At first, information regarding geography, geology, hydrogeology, geophysical data and other relevant data were collected from that particular

study area. Then a reconnaissance was made in the area who were affected by arsenic toxication. During the period, some of the affected tubewell water was tested with arsenic field kits and other relevant parameters. Water was collected in two phases. First phase was in collected March (dry season), 2001 and second phase was collected in June (wet season) 2001. In second time some tubewells were unusable. So, it has taken another water sample from near that place.

5.3. Method of Deep Drilling Location :

On consultation with the local people a site was selected for geological test drilling. The test drilling was done nearly the middle point in the village of Auguankhil and Abhirampur near a mosque nearby most of the shallow tubewells have been affected by arsenic contamination and two deep tubewells have installed for supplying water. The depths of the tubewells are about 200 metres.



Department of Geography and Environment, DU, 2003.

Map-5.1: Location of Shallow Tubewells and Deep Drilling.

5.4. Method of Soil Sampling in the Deep Drilling Location :

Soil sampling is an important part for an environmental research work. The study has collected soil sample from the test hole as follows :

A. Borhole soil sample collected in plastic sealed syringe within polythene. Samples have collected for every five feet cutting and when the colour has changed in liquid soil during drilling time, studied and prepared in plastic container bags for laboratory analysis.

B. After five feet interval, sediments were sampled with sampler, a part of the sample was splitted, studied and other part of the sample was taken by 5 inch shringe and was preserved by waxing so as to protect moisture content and other ingredients and preserved for laboratory study. Sample sediment has collected through vertical deep drilling so as to observe vertical variation in the sediment column.

C. In addition to the sampling after five feet sampling of sediments was done as when it was felt there was some changes in texture, colour and grain size in the lithology.

D. During the drilling operation a detailed geological log was prepared (pp.116-119).

E. During laboratory analysis of sediment samples again the sediment were studied and added more information if it was found.

F. It has spread the samples in largely, then from each ten inches depth, one sample was randomly selected for analysis. The chemical analyses done for those materials are Magnesium, Calcium, Arsenic, Chloride, Iron, Sulphate and Nitrate.

The results of the chemical analyses have been plotted in the graph sheet along with Japanese, American and Bangladeshi standard. It is done only for Arsenic.

5.5. Techniques of Socio-economic Data Collection:

Groundwater arsenic contamination of Ramganj Upazila has been suspected to be the biggest arsenic calamity in Bangladesh. Water is the most available natural resource of Bangladesh. But it is not safe for man. Eight villages and a crowded place (Bazar) were selected for the research work. Out of the twenty shallow tubewells and two deep tubewells were taken as a sample which were highly arsenic affected. Identified the patients and every person was interviewed who were used those tubewell's water in these eight studied villages. Person to person and door to door survey was conducted in the study area with a structured questionnaire on the basis of selected socio-economic condition, socially and psychologically affected arsenicosis patients and their reaction, physical conditions of the patients and environmental variables.

5.6. Determination of Chemical Used for Soil and Water Data Analysis:

The name of the chemicals are given below which is used for Soil and Water Data Analysis.

Table-5.1: Name of Chemicals

Sl.	Chemicals name	State	Origin	Grade
1.	Arsenic (AS_2O_3)	Fine	E.Merck (Germany)	GPR
2	Ammonium Purpurate	Solid	BDH (England)	GR
3	Ammonium Chloride (NH_4Cl)	Solid	E.Merck (Germany)	GR
4	Ammonium acetate (NH_4OAC) (Buffer Iron)	Liquid	BDH (England)	AnalaR
5	Ammnium (NH_4OH)	Concentrated	BDH (England)	GPR
6	Barium Chloride ($BaCl_2$)	Solid	E.Merck (Germeby)	GPR
7	Chloroform	Liquid	BDH (England)	GPR
8	Di-sodium Salt (EDIA)	Solid	E.Merck (India)	GPR
9	Ethyl Alcohol	Liquid	E.Merck (Germany)	GPR
10	Glycrine	Concentrated	Bangladesh	NSC
11	Hydroxylamine hydrochloride (NH_2OH HCL)	Solid	E.Merck (Germany)	GR
12	Hydrochloric acid (HCL_2)	Liquid	BDH (England)	AnalaR
13	Lead acetate	Solid	E.Merck (Germany)	GPR
14	Morpholine	Liquid	E.Merck (Germany)	AnalaR
15	Nitric acid (HNO_3)	Concentrated	BDH (England)	AnalaR
16	Orthophenanthroline	Solid	BDH (England)	GPR
17	Potassium chromate ($K_2Cr_2O_4$)	Solid	E.Merck (Germany)	GR
18	Phenol	Solid	BDH (England)	GPR
19	Potassium hydroxide (KDH)	Solid	BDH (England)	GPR
20	Potassium Iodide (KI)	Solid	E.Merck (Germany)	GR
21	Potassium Nitrate (kNO_3)	Solid	E.Merck (Germany)	GPR
22	Sodium hydroxide (NaOH	Solid	BDH (England)	GPR
23	Sodium chloride (NaCl)	Solid	E.Merck (India)	GPR
24	Silver nitrate ($AgNO_3$)	Solid	E.Merck (Germany)	GPR
25	Sulphuric acid (H_2SO_3)	Concentrated	BDH (England)	GPR
26	Silver diethyldithiocabamate (SDDC)	Solid	E.Merck (Germany)	GPR
27	Stannous Chloride ($SnCl_2$)	Solid	BDH (England)	GPR
28	Sodium Sulphate (NO_2SO_4)	Solid	E.Merck (Germany)	GPR
29	Zinc (Zn)	Granular	Loba (India)	GPR

5.7. Analytical Methods:

Analytical method is the most important method of investigation and is widely used in all branches of science which are related to chemistry. Analytical method is divided into two parts. Field kit Test Method of shallow tubewells and Laboratory Method.

5.7.1. Field kit test method of shallow tubewells:

Field kit test method is not a proper method for chemical analysis in any branch of science. This method uses only for primary idea in a particular area. It has used Field kit Test Method for determination of arsenic, pH, dissolve oxygen, bicarbonate and temperature parameters.

5.7.1.1. Arsenic

Arsenic appears in nature primarily in the form of sulfides in association with sulfides of ores of silver, lead, copper, nickel, antimony, cobalt and iron. Trace amounts of arsenic are found in water, soils and other environmental media. Uncontaminated soil generally contains less than 40 μg arsenic per gram of soil.

Arsenic contamination of groundwater is a major public health problem at Ramganj in Lakshmipur. The majority of tubewells in the study area are being screened for arsenic using field test kits. The Field Kit Technique used by Merckoquant (MERCK), Germany is based on the "Analytical Test Strips" technique.

The Analytical Test Strips Method is one of the familiar technique which is being considered for testing of the wells by different NGOs in Bangladesh.

This technique can be used as rapid, low cost, field level qualitative screening method and can detect arsenic contamination as low as 0.1-3 mg/l level.

In groundwater, arsenic usually occurs as arsenite (As-III) and arsenate (As-V). To determine the arsenic in water arsenate is to be reduced to arsenite by the reducing agents zinc and hydrochloride acid. This two reagents are known as arsenic field-test kit. This arsenic field test kit works on the principle of reducing first inorganic soluble arsenic (As-III and As-V) to arsite gas (H_3A_S). The arsine gas then reacts with mercury bromide impregnated on strips to form mercury bromide halogenides that discolour the test strip (disc paper). The colour changes from yellow to reddish brown depending on the concentration of arsenic in the test water. In absence of arsenic in the water sample, no colour is produced on the paper.

DETERMINATION OF ARSENIC

Apparatus

(i) Arsenic Test kit Box

Merckoquant, Germany.

Chemicals

(1) Zinc (Mesh)

(2) Hydrochloric Acid (HCL)

(3) Analytical test strips.

Procedure for Arsenic Test in Water by Merckoquant Field Kit :

1. First, holding the reaction zone of the test strip downwards, insert the test strip into the slit in the cap of the reaction vessel such that the cap divides the strip into two approximately equal segments.

2. With the aid of the syringe placed 5 ml (the wells were pumped for at least 15 minutes) of test solution (water sample) in the reaction vessel, added 1 measuring spoonful of reagent 1 (Zinc mesh) and swirled.

3. Added 10 drops of reagent 2 (HCL) and closed the reaction vessel immediately with the cap.

4. Allowed to stand for 30 minutes, shaking gently 2-3 times. Removed the test strip, immersed briefly in water, shaked off excess liquid and compared the reaction zone with the colour scale (attached with the strips box) corresponding to concentration ranges provided. The concentration ranges provided on the test chart are 0, 0.1, 0.5, 1.0, 1.7, 3 mg/l and recorded the content of arsenic in the format.

This method gives a qualitative idea about the arsenic concentration with the intensity of staining.

In Bangladesh, very few institutions have laboratory facilities to test water for arsenic, these methods are often very costly and also time consuming. There are several field kits available in Bangladesh.

The Department of Occupational and Environmental Health (DOEH), NIPSOM uses the field kit technique to delect arsenic in water since 1995. A scientist Hiromi Hironaka of Asia Arsenic Network (AAN) has developed this Field Kit Method and DOEH has the capacity to produce this kit. The

principle of this method is alsomt same as the above mention field kit method that is used this research.

5.7.1.2 pH :

pH is an important parameter. The pH of a solution is defined as the negative common logarithm of the hydrogen ion activity, and can be described as aH^+; pH = -log10 ($^aH^+$), $[H^+]$ = hydrogen ion concentration. It also describes whether a solution is acidic pH = 10 + < 7, neutral pH = 7 or basic (pH>7).

In a dilute solutions the hydrogen ion activity is approximately equal to the concentration of hydrogen ion.

The pH of an aqueous sample is usually measured electrometrically with a glass electrode. The pH of most raw water sources lies within the range 6.5 – 8.5 (Webber and Stumm, 1963). pH is related, in several different ways, to almost every other water quality parameter as aqueous chemical equilibrium invariably involve hydrogen (and hydroxyl) ions. Natural waters contain gases, colloidal matter and a variety of electrolyte and non-electrolyte material; these, together with pH, determine the extent of corrosion in a system and define the "aggressively" of the water.

A pocket or pen pH meter with glass electrode and automatic temperature compensator was used to determine the pH. The pH meter was calibrated using the standard buffer solution prior to sampling. The recommended guideline value for pH is 6.5 – 8.5 (WHO, 1988).

DETERMINEATIAN OF pH

Instruments :

(i) pH meter (compact pH meter B.212). Horiba Ltd. Kyoto Japan

(ii) Beaker, 100 ml

Reagents

(a) Standard buffer solutions of pH 4.0 (potassium hydrogen phthalate) and pH 7 or 9.2 (sodium tetraborate buffer) Harbia Ltd, Kyoto, Japan.

Procedure

1. Into a 100 ml beaker place on 50 ml of sample solution
2. Switch on the pH meter and adjust with buffers.
3. Placed the electrodes into the sample and read the pH.

5.7.1.3. Dissolved oxygen

The primary effect of dissolved oxygen in water is an oxidation-reduction reactions, involving iron, manganese, copper, and compounds that contain nitrogen and sulfur.

There are many disadvantages in distributing a water low in dissolved oxygen. Low values of dissolved oxygen can cause killing of fish and other animals of water kingdom. It is a test, which indicates the sanitary status of a water. Oxygen is a highly active gas and its presence in water may contribute to its corrosiveness. The dissolved oxygen also suggested whether

the processes undergoing change are aerobic or anaerobic. A good water should have solubility of oxygen about 15 mg/l litre at 0°C and 7 mg/l litre at 35°C (Didar et al., 1991).

DETERMINATION OF DISSOLVED OXYGEN

One of the most useful titrations involving iodine is that originally developed by winkler to determine the amount of oxygen in samples of water. The dissolved oxygen content is not only important with respect to the species of aquatic life which can survive in the water, but is also a measure of its ability to oxidise organic impurities in the water. Despite the advent of the oxygen-selective electrode direct titrations on water samples are still used extensively (Furman, 1962; Vogel's, 1989).

In order to avoid loss of oxygen from the water sample it is 'fixed' by its reaction with manganese (II) hydroxide which is converted rapidly and quantitatively to manganese (III) hydroxide.

$4\ Mn(OH)_2 + O_2 + 2H_2O \rightarrow 4\ Mn(OH)_3$

Instruments

(i) DO_2 meter (JENWAY 9071) with a temperature probe

Procedure

To get accurate dissolved Oxygen (DO_2) readings a bucket was held upto the mouth of the well being immersed into the water and the tubewell was pumped continuously for 15 minutes so that it overflowed to minimize air entrapment. Then the oxygen probe was immersed into the water and the

readings were recorded. The DO_2 meter was calibrated every morning prior to sampling.

5.7.1.4. Bicarbonate :

Bicarbonate/alkali is the name used for some of the compounds of the alkali metals. When added it to water, these oxides from the hydroxides, solutions of the hydroxides turn litmus extract blue, react with acids to give neutral salts and have a corrosive action on the skin. All the alkali metals from similar compounds. The reaction with litmus is a properly common to all alkalis, but other compounds also form litmus blue. (Encyclopedia Americana, vol. 1).

DETERMINATION OF BICARBONATE

Dissolved carbonate (CO_3^{--}) and bicarbonate (HCO_3^{-}) in water, including soil solutions, as conventionally carried out, is often termed "total alkalinity" because it usually includes small amounts of phosphates, borates, and silicates as well as the two species of carbonate in waters and soil solutions are generally small enough to be negligible.

Apparatus :

(i) Bicarbonate/Alkalinity Test Kit Box HANNA instrument, Italy.

Chemicals

(1) Phenolphthalein indicator (pH range 8.3 – 10.3)

(2) Bromphenol/thymol blue indicator [pH range (base) 8.0 – 9.6]

(3) Hydrochloric Acid (0.1%)

Procedure for Bicarbonate Test in water by HANNA instruments Field Kit

(a) Taken 5 ml of sample in the supplied container that was marked 5 ml to 20 ml.

(b) Added 2-3 drops of phenolphthalein indicator it might slight pink colour appeared in some samples.

(c) Added 2-3 drops of bromphenol blue as indicator, it has been violet colour.

(d) Titrated very slowly by hydrochloric acid (0.1%), untill the colour changed from violet to yellow.

(e) Noted the reading.

Calculation: Bicarbonate (HCO_3^-) mg/l = Reading x 100

5.7.1.5. Temperature :

In general, the rates of chemical reactions decrease with decreasing temperature. The relative concentrations of reactants and products in chemical equilibrium can also change with temperature. Temperature can, therefore, affect every aspect of the treatment and delivery of potable water.

Temperature measurements at the well head were taken immersing the temperature probe of the DO_2 meter into the water and the stable reading were recorded.

5.7.2. Laboratory method :

Laboratory method is the most accurate method of measuring the properties of water and soil. To collect sample from study area to analyze them independently in a laboratory. All the groundwater and soil samples were analyzed to determine the concentration of some major cotions, anions and for arsenic. All the samples were analyzed at the Environmental Laboratory of the Geography and Environment Department in Dhaka University.

Arsenic was analysed in SDDC (Silver Diethyldithio carbonate) method using spectrophotometre (JENWY 6300, U.K. and ANALOGUE S1O4, UK) following the standard solution instructed by manufacturer.

Chloride, Calcium and Magnesium were analyzed by EDTA (Ethylenediamine Tetra Acetic Acid) Titration method using $AgNO_3$. Solution EDTA (Ethylenediaminaletracetic acid disodium salt) solution (0.02N and 0.01M) respectively. Iron was analyzed in spectraphotometric – 1-10 phenontroline method using spectrophotometre. Nitrate was analyzed in phenoldisulphonic acid-spectrophotometric method. Sulphate was analyzed in turbidimetric method.

To fulfil the objective of the research to identify the sources of arsenic and other unfriendly toxic elements and compounds which contaminated the groundwater are selected for chemical analysis. The chemical analyses done for those materials are Magnesium, Calcium, Arsenic, Chloride, Iron, Sulphate and Nitrate. The results of the chemical analyses have been plotted in the graph sheet along with plotting permissible limit of those elements in drinking water by the World Health Organization and Bangladesh standard.

5.7.2.1. Water analysis:

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms. The environment, economic growth and development of Bangladesh are all highly influenced by water – its regional and seasonal availability and the quality of surface and groundwater.

Clean water is essential to human survival, and the earliest environmental regulations deal with contamination of local water sources. Contamination of water resources has always occurred from a variety of anthropogenic activities, and, as population density increased, rivers, lakes, and even oceans became contaminated. Direct discharge of industrial waste, domestic sewage, pesticide, runoff from agricultural land and acid rain all contributed to this contamination. Groundwater may be polluted by landfill leachate, leaking storage tanks and pipelines, oil and gas wells, irrigation practices, waste disposal by direct underground injection and other process. Groundwater and surface water earn also contaminate each other as they are not isolated.

Water analysis has had a long history. An early test for the suitability of drinking water was used in Istambul in the seventeenth century. Weighed pieces of cotton were soaked in the water and dried. (Kebbekus and Mitra, 1998). Those water samples which gave the best. Recent developments have made sophisticated analysis methods ever more important. Water is analyzed for a large number of possible substances, depending on its proposed use. Drinking water is probably the most thoroughly tested, with tested for pH, turbidity, metals, inorganic anions, and now, toxic organic

materials such as pesticides and trihalomethanes being done routinely. In addition, more intangible qualities such as odor and taste are determined. A large number of different tests are needed to monitor such properties as colour turbidity, taste odor, acidity, hardness, conductivity, solids, and oxygen demand as well as more specific chemical analyses for metals, inorganic non-metallic constituents, pesticides and radioactivity.

5.7.2.1.1. Arsenic

Arsenic occurs naturally in all environmental media and is usually present in the form of compounds with sulfur and with many metals (copper, cobalt, lead, zinc, etc.). The average concentration in the earth's crust is about 2 mg/kg (Guidelines for Canadian drinking water quality, 1978). Although arsenic exists in various valence states and in both organic and inorganic forms, the levels of environmental arsenic are normally reported in terms of total arsenic. In some localized geographic areas, commercial use and production of arsenic compounds have resulted in significant elevation in the amounts of environmental arsenic above natural background levels.

Many arsenic compounds are water-soluble and, thus, contamination of water can occur. The chemical form of arsenic in water has not been fully elucidated, but both tri and pentavalent forms have been identified some forms of organic arsenic have been found in water. Geothermal discharges in New Zealand have been found to contain significant quantities of arsenic. In spite of its ubiquitousness in nature, most of the arsenic found in water derives from industrial discharges; the highest concentrations other than those occurring naturally in spring-waters are usually in areas of high industrial activity.

A large number of water supplies contain very low levels of arsenic, i.e. well below 10 µg litre. In special situations, gross contamination of well supplies has occurred and several thousand micrograms of arsenic per litre of water have resulted. There is little information concerning the form or species of arsenic in water supplies.

Various manifestation such as hyperpigmentation, keratoses, and lung cancer have been observed where high occupational exposure to arsenic has occurred (WHO, 1984).

DETERMINATION OF ARSENIC

Of the number of procedures available for the determination of minute amounts of arsenic, only one will be described, viz. the spectrophotometeric SDDC method. It possesses great sensitivity and precision and is readily applied colorimetrically or spectrophotometrically.

SPECTROPHOTOMETRIC SDDC METHOD

One of the best method for arsenic analysis, HVG (Hhydride vapour Generator). Atomic Absorption Spectrophotometer is an another profuse introduced method.

Apparatus

i) 5 ml pipette

ii) 5 ml cylinder

iii) Dropper

iv) Generator

v) Spectrophotometer

vi) Funnel

Regents :

1. Potassium Iodide Solution : Dissolved 15 g of solid KI in distilled water to make 100 ml solution.

2. Stannous Chloride Solution : Dissolved 40 g hydrated tin (II) Chloride in 100 ml concentrated hydrochloric acid.

3. SDDC Solution : Dissolved 0.75 g of SDDC + add 25 ml chloroform + add 2.5 ml morpholine and mixed 222.5 ml distilled water.

4. Hydrochloric acid concentrated (12 N).

5. Zinc : Used 20 – 30 mesh or granulated arsenic free.

6. Lead acet.

7. Standard arsenic Solution, 1000 ppm of As : Dissolved 1.320 g of As_2O_3 in distilled water and diluted the solution to 1 litre (1000 ml). This solution contains 1000 ppm As.

From this solution, prepared a secondary standard solution by using formula/ equation this solution contained 100 ppm As.

Taken aliquots of 0.05, 0.1 and 0.2 ml for preparation of 0.05, 0.1 and 0.2 ppm respectively from 100 ppm stock As solution in a series of 100 ml volumetric flasks for the standard curve.

Formula/equation

$$V_1 \times S_1 = V_2 \times S_2$$

Here,

V_1 = How much (ml)

S_1 = How many ppm

S_2 = From how many ppm

V_2 = Measurement that we want for a series of standard curve.

(Didar et al., 1991)

Method

(a) Taken 25 ml of sample in a generation.

(b) Ad 2 ml of potassium iodiate solution.

(c) Add 5 ml of hydrochloric acid concentration solution.

(d) Add 10 drops of $Sncl_2$ solution.

(e) Poured SDDC solution in the bend funnel.

(f) Finally added zinc while confining the bend funnel. Let stand for 30 minutes. Then pouring the SDDC in container, recorded the absorbance on spectrophotometer at 525 nm by using distilled water blank.

Processed the standard arsenic solution of different concentrations in similar way and recorded the absorbance for each. Plotted a standard curve from these values and deduce the total arsenic content of the sample in mg/l by comparing the absorbance of sample with the standard curve.

5.7.2.1.2. Iron :

Iron (Fe) is a metallic chemical element. The symbol for iron is derived from the Latin word for the metal, ferrum. It is a silvery white solid metal, appears in the periodic table as TRANSITION ELEMENT.

Iron is the fourth most abundant element by weight in the earth's crust. In water it occurs mainly in the divalent and trivalent (ferrous and ferric) states (USEPA, 1976). Both cast iron and steel pipes are employed for drinking-water distribution to the consumer. In the production of potable water, various salts of iron are used as coagulating agents.

Iron in surface water is generally present in the ferric (Fe III) state. The concentration of iron in well aerated water is seldom high, but under reducing conditions, which may exist in some groundwater, lakes or reservoirs, and in the absence of sulfide and carbonate, high concentrations of soluble ferrous iron may be found. Concentrations of iron greater than 1 mg litre have been reported to occur in groundwater. The presence of iron in natural waters can be attributed to the dissolution of rocks and minerals, acid mine drainage, landfill leachates, sewage, or iron-related industries.

Iron is generally present at low concentrations in the atmosphere as a result of emissions from the iron and steel industry, thermal power plants, and incineration, but few data are available on levels of iron in the atmosphere.

The iron content of foods varies considerably. Cereals (mean 0.0295 mg/g) and meat (0.0262 mg/g) appear to be the main dietary sources of this element, the iron concentration of most other natural foods being less than 0.020 mg/g. Levels may be somewhat higher in foods fortified with iron or in food cooked in iron utensils. Evidence suggests that the iron content of foodstuffs decreases during boiling (WHO, 1984).

DETERMINATION OF TOTAL IRON

There are many methods available for determining iron (Fe) gravimetrically, volumetrically or colourimetrically. Number of methods have been employed to assess the availability status of Fe in water and soils. The spectrophotometric-1, 10 phenontroline method described in the below .

SPECTROPHOTOMETRIC-1, 10 PHENOTROLINE METHOD

This is undoubtedly the most accurate method for determining inter alia the concentration of substances in solution, but the instruments, are, of necessity, more expensive. A spectrophotometer may be regarded as a refined filter photoelectric photometer which permits the use of continuously variable and more nearly monochromatic bands of light (Vogel's, 1989).

Apparatus

(i) Spectrophotometer

(ii) 10 ml pipette

(iii) 5 ml conical flask/bottle

(iv) Measuring cylinder

(v) Volumetric flask

(vi) Dropper

Reagents

1. Hydroxylamine hydrochloride solution : Dissolved 10 g of hydroxylamine hydrochloride in distilled water to make 100 ml solution.

2. Ammonium acetate buffer solution : Dissolved 100 g of ammonium acetate in 60 ml of distilled water and added 280 ml glacial acetic acid.

3. Orthophenothroline Solution : Dissolved 0.3 g of orthophenonthroline monohydrate in distilled water by shaking and heating upto 80°C. Cool the solution and added water to make a volume of 100 ml.

4. Standard iron solution, 1000 ppm of Fe : Mixture 102 ml of accate acid with 70 ml of ammonium acid (NH_4OH) upto 1L distilled water. This solution contained 1000 ppm Fe.

From this solution, prepared a secondary standard solution by using formula/equation this solution contained 10 ppm Fe.

Took an aliquots of 20 ml, 50 ml and 70 ml preparation of 2 ppm, 5 ppm and 10 ppm, respectively from 10 ppm stock Fe solution in a series of 100 ml volumetric flasks for the standard curve.

Formula/equation

$$V_1 \times S_1 = V_2 \times S_2$$

Here,

V_1 = How much (ml)

S_1 = How many ppm

S_2 = From how many ppm

V_2 = Measurement that we want for a series of standard curve.

(Didar et al., 1991)

Method

(a) Took 5 ml of sample in a conical flask

(b) Add 8 drops of hydroxylamine solution.

(c) Add 20 drops of orthophenanthroline solution

(d) Finally added 22 drops of buffer iron solution. Let stand for 10 or 20 minutes then stable faint pink or red color appeared. Then recorded the absorbance on spectrophtometre at 490 nm by using distilled water blank.

Processed the standard iron solution of different concentrations in similar way and recorded the absorbance for each. Plotted a standard curve from these values and deduce the total iron content of the sample in mg/l by comparing the absorbance of sample with the standard curve.

Table-5.2: Property of Iron

PROPERTIES OF IRON	
Atomic number	26
Atomic weight	55.847
Isotopes, stable	54, 56, 57, 58
Isotopes, unstable	52, 53, 55, 59
Melting point (^{o}C)	1535
Boiling point (^{o}C)	3000
Specific gravity (grams per cc)	7.87
Hardness (Mohs' scale)	4.0 – 5.0
Abundance in lithosphere (percent)	5.000
Oxidation states	+2, +3, +4, +6

Source : Colliers Encyclopaedia Vol. 13

5.7.2.1.3. Calcium

Calcium is a metalic element. It is a member of the alkaline earth family which also includes barium, radium and strontium. Calcium was discovered by the English chemist Sir Humphry Davy in 1808. It is the third most abundant metal in the earth's crust. Calcium plays an important role in the physiological chemistry of living organisms.

Calcium occurs widely and abundantly in water and soils as the carbonate phosphate, Silicate and Sulphate. Groundwater from most of the Bangladesh aquifers appear to be of calcium-bicarbonate type with exception of more saline groundwater, predominantly near the coast, which have sodium as the dominant cation.

DETERMINATION OF CALCIUM

The determination of calcium is more complicated; many chemical interference are encountered in the acetylene – air flame and the use of "releasing agents" such as strontium chloride, lanthanum chloride or EDTA is necessary.

TITRIMETRIC METHOD

The operation of determining the strength of an unknown solution by allowing it to react with the standard solutions is called titration. The process of titration consists of addition of the solution from a burette to a measured volume of a solution of the other reactant or to a weighed sample dissolved in water, until the same number of equivalents of each substance has been used. The end point in the titration is detected by means of a suitable

indicator. Phenolphthalein, which is red in basic solution and colourless in acid solution, is often used for acid-based titrations. The end point or point at which a permanent colour change just occurs after thorough mixing, is very sharp. Only a drop or fraction of a drop will bring about a colour change.

Apparatus

i) 250 ml conical flask.

ii) Microburette

iii) 50, 100, 500 and 1000 ml volumetric flask.

iv) 2 and 5 ml pipette

v) Fitting stand

vi) Stirrer : JENWAY LTD, Felsted Dunmow Essex England CM6 3LB Model 1100.

Reagents

1. Hydroxylamine hydrochloride solution: Dissolved 10 g of hydroxylamine hydrochloride in distilled water to make 100 ml solution.

2. Potassium hydroxide Solution (12N) : Dissolved 336.5 g of KOH in distilled water to make the volume 500 ml.

3. Murexide indicator : Mixed 0.2 g of ammonium purpurate and 100 g of sodium chloride and grind thoroughly.

4. Standard EDTA Solution (0.01 M) : Dissolved 3.723 g of di-sodium salt of EDTA in distilled water to prepare 1L of solution.

Method

(a) Taken 50 ml of sample in a conical flask.

(b) Added 1 ml of hydroxylamine hydrochloride solution and 1 ml KOH solution

(c) Added a pinch of Murexide indicator

(d) Titrate against EDTA Solution until the pink colour of the solution turns to blue.

Calculation

For calcium (Ca^{2+})

$$\text{Calcium (mg/l)} = \frac{T \times 400.5 \times 1.05}{V}$$

where,

T = Volume of titrant (ml)

V = Volume of sample (ml)

For calcium hardness as $CaCO_3$

$$\text{Calcium hardness (mg/l)} = \frac{T \times 1000 \times 1.05}{V}$$

where,

T = Volume of titrant (ml)

V = Volume of Sample (ml).

Table-5.3: Property of Calcium

PROPERTIES OF CALCIUM	
Atomic number	20
Atomic weight	40.08
Isotopes, stable	40, 42, 43, 44, 46, 48
Isotopes, unstable	38, 39, 41, 45, 49
Melting point (°C)	839
Boiling point (°C)	1,484
Specific gravity (20°C)	1.55
Density (grams per cc)	
Hardness (Moh's scale)	1.5
Abundance in lithosphere (percent)	3.63
Valence /	3.5
Oxidation state	+2

Source : Collier's Encyclopaedia Vol. 5, Britanica Encyclopaedia Vol. 2

5.7.2.1.4. Chloride

Chloride is widely distributed in nature, generally in the form of sodium (N_aCl), potassium (KCl) and calcium (C_aCl_2) salts. It constitutes approximately 0.05 per cent of the lithosphere (Natural Research Council of Canada Associate Committee on Scientific Criteria for Environmental

quality, 1971). By far the greatest amount of chloride in the environment is present in the oceans.

The presence of chloride in natural waters can be attributed to dissolution of salt deposits, contamination resulting from salting of roads to control ice and snow (Muray, Ennstand, Ralaston 1976, 1971), discharges of effluents from chemical industries (Litre 1971), oil-well operations (Fetty John, 1971), sewage discharges, irrigation drainage, contamination from refuse leachates, and seawater intrusion in coastal areas (Bond and Strab, 1973). Each of these sources may result in local contamination of both surface-water and groundwater. The chloride ion is highly mobile, however, and is eventually transported into closed basins or to the oceans.

Chloride is generally present at low concentrations in natural surface-water. Levels in unpolluted water are often less than 10 mg/litre and may often be less than I mg/litre (WHO, 1984).

DETERMINATION OF CHLORIDE

Chloride is one of the major constituents found in all natural and groundwaters in different concentrations. The chlorides of Ca, Mg, K and Na are all very soluble. Chloride is usually the anion in extracts of saline soil and the concentration may reach several hundred million equivalents per litre. Chloride is specifically toxic to some trees and crops.

TITRIMETRIC METHOD

The well known Mohr volumetric method is satisfactory for the determination of chloride in aqueous soil extracts.

Apparatus

(i) 250 ml conical flask

(ii) Microburette

(iii) 50, 100, 500 and 1000 ml volumetric flask.

(iv) 2 and 5 ml pipette

(v) Fitting stand

(vi) Stirrer : JENWAY LTD, Felsted Dunmow Essex England CM6 3LB, Model 1100.

Reagents

(1) Silver nitrate solution (0.02N)

Dissolve 3.397 g of silver nitrate in distilled water and dilute to 1 Liter. Stored the Solution in a dark glass bottle.

(2) Potassium chromate indicator:

Dissolve 10 g of potassium chromate in about 20 ml of distilled water.

Method

(a) Taken 10 ml of sample in a flask and 3-5 drops of potassium chromate indicator

(b) The colour of sample becomes yellow

(c) Titrate against silver nitrate solution until a persistent brick colour appears.

Calculation

$$\text{Chloride (mg/l)} = \frac{V \times N \times 35.45 \times 1000}{S}$$

where

V = Volume of the titrant (ml)

N = Volume of the sample (ml)

N = Normality of the titrat

Table-5.4: Property of Chloride

PROPERTIES OF CHLORIDE	
Atomic number	17
Atomic weight	35.453
Isotopes, stable	35, 37
Isotopes, unstable	33, 34, 36, 38, 39
Melting point (^{o}C)	-100, 98
Boiling point (^{o}C)	-34.6
Density (1 atm, 0^{o}C)	3.214 g/l
Oxidation states	-1, +1, +3, +5, +7

Source : Colliers Encyclopaedia Vol. 6

5.7.2.1.5. Magnesium

Magnesium is a silvery white metallic element of the ALKALINE EARTH METAL group, the lightest structural metal. It is the eight most abundant element in Earth's crust (about 2.5 per cent). Magnesium occurs in nature as a mixture of three isotopes. It is a very strong reducing agent reacting with most acids or with boiling water to liberate hydrogen, but it is resistant to most alkalies.

DETERMINATION OF CALCIUM AND MAGNESIUM

In the combined determination of calcium and magnesium, Eriochrome Black T is used as the indicator. The optimum pH for the formation of magnesium EDTA complex is 10 this is maintained by a buffer solution. Calcium is complexed before magnesium and the indicator changes from red to blue when the magnesium end point is reached. The color complex has a greater ionization constant than the EDTA-Mg complex (Didar et al, 1991).

EDTA TITRIMETRIC METHOD

Calcium and magnesium concentration in water may vary from zero to several hundred milligrams per litre, depending on the source and treatment of water whereas in soil the Ca and Mg contents vary widely depending on soil pH. The atomic absorption spectrophotometry provides an accurate method for the determination of calcium and magnesium. But the simplicity and rapidity of EDTA titration procedure makes it the method of choice for general use.

Apparatus

i) Microburette.

ii) Volumetric flask (50, 100, 500 and 1000 ml).

iii) 2 and 5 ml pipettes.

iv) Measuring cylinder

v) Fitting stand

vi) Stirrer : JENWAY LTD, Felsted Dunmow Essex England CM6 3LB Model 1100.

Reagents

(1) Hydroxylamine hydrochloride Solution : Dissolved 5 g of hydroxylamine hydrochloride (NH_2 OH, Hcl) in 100 ml of distilled water.

(2) Ammonia Buffer Solution : Dissolved 13.5 g of Ammonium chloride in 114 ml of concentrated ammonium hydroxide and distilled water to make the volume 200 ml.

(3) Erochrome Black-T Indicator : Dissolved 0.5 g of Erichrome Black-T dye in 100 ml of 8% Ethyl Alcohol.

(4) EDTA Standard (0.01M) Solution : Dissolved 3.723 g of di-sodium salt of EDTA in distilled water to prepare 1L of solution. Stored in a polyethylene bottle.

Method

(a) Taken 50 ml of sample in a conical flask.

(b) Added 1 ml of hydroxylamine hydrochloride solution

(c) Added 3-5 ml of buffer solution.

(d) Added 1-2 drops of Erichrome Blaock-T Indicator.

(e) Titrate against EDTA Solution until the wine red colour of the solution turns to blue.

Calculation

$$\text{Total Hardness (mg/l, as } CaCO_3) = \frac{T \times 1000}{V}$$

where,

T = Volume of titrant (ml)

V = Volume of sample (ml)

Total hardness and calcium hardness of water as mg/l $CaCO_3$ are determined as described earlier. From these values magnesium content is calculated by using following relation.

Magnesium (mg/l) = (T-C) x 0.244

where,

T = Total hardness

C = Calcium hardness.

Table-5.5: Property of Magnisium

PROPERTIES OF MAGNESIUM	
Atomic number	12
Atomic weight	24.312
Melting point	651°C
Boiling point	1.107°C
Specific gravity	1.74 (20°C)
Valence	2

Source : Encyclopaedia Britanica Vol. 7.

5.7.2.1.6. Sulphate

The majority of sulfates are soluble in water, the exceptions being the sulfates of lead, barium, and strontium (McKee and wolf, 1963). Dissolved sulfate is considered to be a permanent solute of water. It may, however, be reduced to sulfide, volatilized to the air as H_2S, precipitated as an insoluble salt, or incorporated in living organisms.

Sulfates are discharged into the aquatic environment in the wastes from many different industries. Atmospheric sulfur dioxide (SO_2), formed by the combustion of fossil fuels and emitted by the metallurgical roasting processes, may also contribute to the sulfate content of surface-water. Sulfur trioxide (SO_3), produced by the photolytic or catalytic oxidation of sulfur dioxide, combines with water vapor to form sulfuric acid, which is precipitated as "acid rain" or snow.

Sulfate is not removed from water by conventional water treatment methods. Sulfate concentrations of bottled mineral water marketed in European Communities average 223 mg/litre (range 0.1182 mg/litre). High sulfate concentrations in water may contribute to the corrosion of metals in the distribution system, particularly in waters having low alkalinity. (WHO, 1984).

DETERMINATION OF SULPHATE

Once in solution, soil/water sulphate can be determined gravimetrically, volumetrically, colorimetrically, conductimetrically or turbidimetrically.

TURBIDIMETRIC METHOD

The determination of sulphate through the turbidity developed on precipitation as $BaSO_4$ (Barium Sulphate) has long been an attractive and much used method. Sulphate may be determined by the turbidity of suspended barium sulphate.

Apparatus

(i) Spectrophotometer

(ii) Conical flask

(iii) Pipettes (10 ml, 5 ml)

(iv) Beaker

(v) Filter paper (whatman No. 44).

Chemicals

(1) Glycrine : Laboratory reagent

(2) Hydrochloric acid (Hcl), 6N

(3) Barium chloride : Finely divided $Bacl_2$, crystal (20 to 60 mesh).

(4) Sulfate Extraction Solution: Mixed 57.5 ml glacial acetic and 18 ml ammonia in distilled water and dilute to 500 ml (only for soil extraction).

(5) Standard sulphate solution : Dissolved 14.79 mg anhytron Na_2SO_4 (Sodium Sulphate) in distilled water and dilute 100 ml. This standard stock solution contains 10 mg/L SO_4^{2-}.

From this standard solution, taken 1 ml, 5 ml and 10 ml by using equation that describe earlier for preparation of 1 ppm, 5 ppm and 10 ppm respectively from standard sulphate solution in a series of 100 ml volumetric flasks for the standard curve.

Methods/procedures

(a) Taken 10 ml of samples in a volumetric flask.

(b) Added 5 drops of glycrine.

(c) Added 8 drops of HCL.

(d) Added a pinch of $BaCl_2$ crystals and mix throughly.

(e) Let stand for 20 minute and then swirl the flask.

For Soil

(f) Taken 1 g soil in conical flask and added 25 ml of sulfate extraction solution

(g) Shaked the flask throughly.

(h) Filtered the suspension through a filter paper.

(i) Taken 3 ml clear aliquot and made the volume upto 10 ml with distilled water. Then the same process.

(j) Read the density of the sample solution by taking absorbance using spectrophotometer at a wave length of 420 nm by using distilled water blank.

Standard Curve

Processed the standard sulphate solution of different concentration in similar way and recorded the absorbance for each. Plotted a standard curve from these values and deduce the total sulphate content of the sample in mg/l by comparing the absorbance of sample with the standard curve.

5.7.2.1.7 Nitrate :

Nitrates are widely present in substantial quantities in soil, in most waters, and in plants, including vegetables. Nitrites also occur fairly widely, but generally at very much lower levels than nitrates. Nitrates are products of oxidation of organic nitrogen by the bacteria present in soils and in water where sufficient oxygen is present. Nitrites are formed by incomplete bacterial oxidation of organic nitrogen. One of the principal uses of nitrate is as a fertilizer; most other nitrogen containing fertilizers will, however, be converted to nitrate in the soil. Nitrates are also used in explosives, as oxidizing agents in the chemical industry and as food preservatives. The main use of nitrites is as food preservatives, generally as the sodium or the potassium salt. Some nitrates in the environment are produced in the soil by fixation of atmospheric nitrogen (bacterial synthesis). Some nitrates are

nitrites are formed when oxides of nitrogen produced by the action of lightning discharge or via man-made sources are washed out by rain. Nitrates and some nitrites are also produced in the soil as a result of bacterial decomposition of organic material, both vegetable and animal.

Because nitrates and nitrites are widespread in the environment, they are found in most foods, in the atmosphere, and in many water sources.

Fertilizer use, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharges, leachates from refuse dumps, and atmospheric washout all contributes to these ions in water sources. Changes in land use may also give rise to increased nitrate levels. Depending on the situation, these sources can contaminate streams, rivers, lakes, and groundwater, especially wells. Contamination may result from a direct or indirect discharge, or it may arise by percolation over a period of time, sometimes after many years. The levels of nitrates in polluted water are almost invariably very much higher than the levels of nitrites, (WHO, 1984).

DETERMINATION OF NITRATE

In specifying the quality characteristics of a water, it is necessary to know the nitrate status of water. In groundwater, nitrate is only rarely an important natural constituent, high concentration may indicate sources of past or present pollution. Nitrate in soil extract or water can be determined either by reduction to ammonia (by using Devarda's alloy) which is then liberated by alkaline steam distillation and titrated against a standard acid or colorimetrically either directly or after reduction of nitrate to ammonia (Didar et al., 1991).

PHENOL DISULPHONIC ACID-SPECTROPHOTOMETRIC METHOD

Several common chemical reactions are available for the determination of soil or water nitrates by phenol disulphonic acid spectrophotometric method. One of them is the development of yellow colour of the soil extract or of water phenol disulphonic in presence of concentred H_2SO_4. The colour becomes yellow when made alkaline with potassium hydroxide.

Apparatus

(i) Spectrophotometer

(ii) 1 ml and 20 ml pipette

(iii) Conical flask.

(iv) Ceramic bath.

Reagents

(1) Phenol disulphonic acid solution: Dissolved 25g white phenol in 150 ml of concentrated ion sulphuric acid and further added 95 ml of concentrated sulphuric acid. Heated for about 2 hours on a water bath, then cool and kept the solution in a dark bottle.

(2) Potassium hydroxide solution (12 N) : Dissolved 336.5 g of potassium hydroxide in distilled water to make the volume 500 ml.

(3) Soil extraction solution (1 N) : Dissolved 37.2786 g potassium chloride (KCL) in 500 ml distilled water.

(4) Standard nitrate solution : Dissolved 0.8815 g Potassium nitrate (KNO_3)

in 500 ml distilled water. This solution contained 100 mg/L NO_3-ions. From this solution, prepared a secondary standard solution by using equation (that describe earlier) this solution contained 10 ppm NO_3- ions.

Taken aliquots of 10 ml, 20ml and 30 ml for preparation of 1 ppm. 2 ppm and 3 ppm respectively from 10 ppm stock NO_3^- solution in a series of 100 ml volumetric flask for the standard curve.

Method

(a) Taken 50 ml of sample in a ceramic bath and evaporate it to dryness on a hot water bath.

(b) After cool the sample added 0.5 ml of phenol disulphoric acid reagent.

(c) Dissolved the residue in the phenol di-sulfuric solution with help of a glass rod.

(d) Mixed 5 ml distilled water and pouring in a 20 ml white bottle.

(e) Added 5 ml distilled water.

(f) Read absorbance of 420 nm. in a spectrophotometer by using distilled water blank.

(g) Processed the standards exactly same way and constracted a calibration curve.

(h) Calculated the NO_3^- concentration in the sample by comparing with standard curve.

5.7.2.2. Soil analysis:

The most common environmental samples are air, water, soil, biological materials and wastes (liquids, solids, or sludges). Each matrix is sampled using different techniques but the underlying concepts are the same in each case. Soil is a complex matrix just as many other environmental materials are many components occur naturally in soil, and others are introduced into it by human activities.

Contamination of soil is now recognized as being as important as air and water pollution. Soil contaminants teach into ground water a rain water percolates through it. Food crops may absorb and concentrate contaminants. Even children may be exposed when they play in contamined soil (Mitra 1998). Soil is quite heterogeneous, containing rocks, trapped gases and liquids. It varies across the surface and with depth this variation is caused by contact with the atmosphere and the biosphere, as well as by the flow of ground water. Most land contamination occurs in the disposal of mining and industrial wastes, or from land disposal of domestic and municipal waste. The mining and industrial waste can contain high concentrations of specific chemicals which may be very toxic. While domestic waste usually is very heterogeneous and contains fewer toxic chemicals. With the explosion of consumer goods. Our society currently produces an enormous quantity of domestic waste which generally buried in landfills. Before 1970s landfills were often chosen haphazardly. As a result, contaminants have leached from many of them and contaminated soil and ground water. Today, sites are selected for their geological characteristics and may be lined with clay and graded to reduce percolation of leachate (Kubbekus and Mitra, 1998).

Another source of soil contamination is leakage from underground storage tanks, especially gasoline tanks. Over the years, these tanks can leak millions of liters and can contaminate large areas of soil as well as ground water. Many old industrial sites are found to be contaminated because in the past. Chemicals were used for variety of activities and little attention was paid to their proper containment. For this reason, we need soil analysis to find the proportion of contamination. Besides soil analysis is need to clean up contaminated land sites and ground water.

Analysis of soil samples in the laboratory was made on samples collected from field. Soil samples were collected by soil auger and spade. Soil samples were digested with strong acid. 5 ml of concentrated nitric acid and 7 ml of concentrated of sulfuric acid were added on 1.0 gram soil sample in a ceramic tube and it was heated at 160°C and digested by wet method. After two hours later when it became near dryness, 10 ml of distilled water and five drops of sulfuric acid (conc.) were added and the liquid was heated at 160°C. After every twenty minutes two drops of sulfuric acid (conc.) was added in three times. Heating was continued until it was digestion completely, when digestion was completed, the sample was adjusted to 100 ml by adding distilled water for analysis in various method.

All the soils parametres were analyzed like the water analyzing method. For sulphate, soils were digested with sulphate extraction solution. Following digestion method, the soil samples were diluted at 1 : 25 soil (g) solution ratio. From the extraction, 3 ml extraction samples were taken so that no sediment was available in and mixed 7 ml distilled water fill up to 10 ml (samples for sulphate). Then it was analyzed like water sample.

Apparatus :

i) Electric Balance

ii) Ceramic Tub

iii) Electric Blast Drying Oven Model J2607, DaJiang Electric Instrument Factor Wuhan, China.

iv) Dropper

v) Volumetric Flask

vi) Filter paper (Whatman No. 44)

vii) Beaker

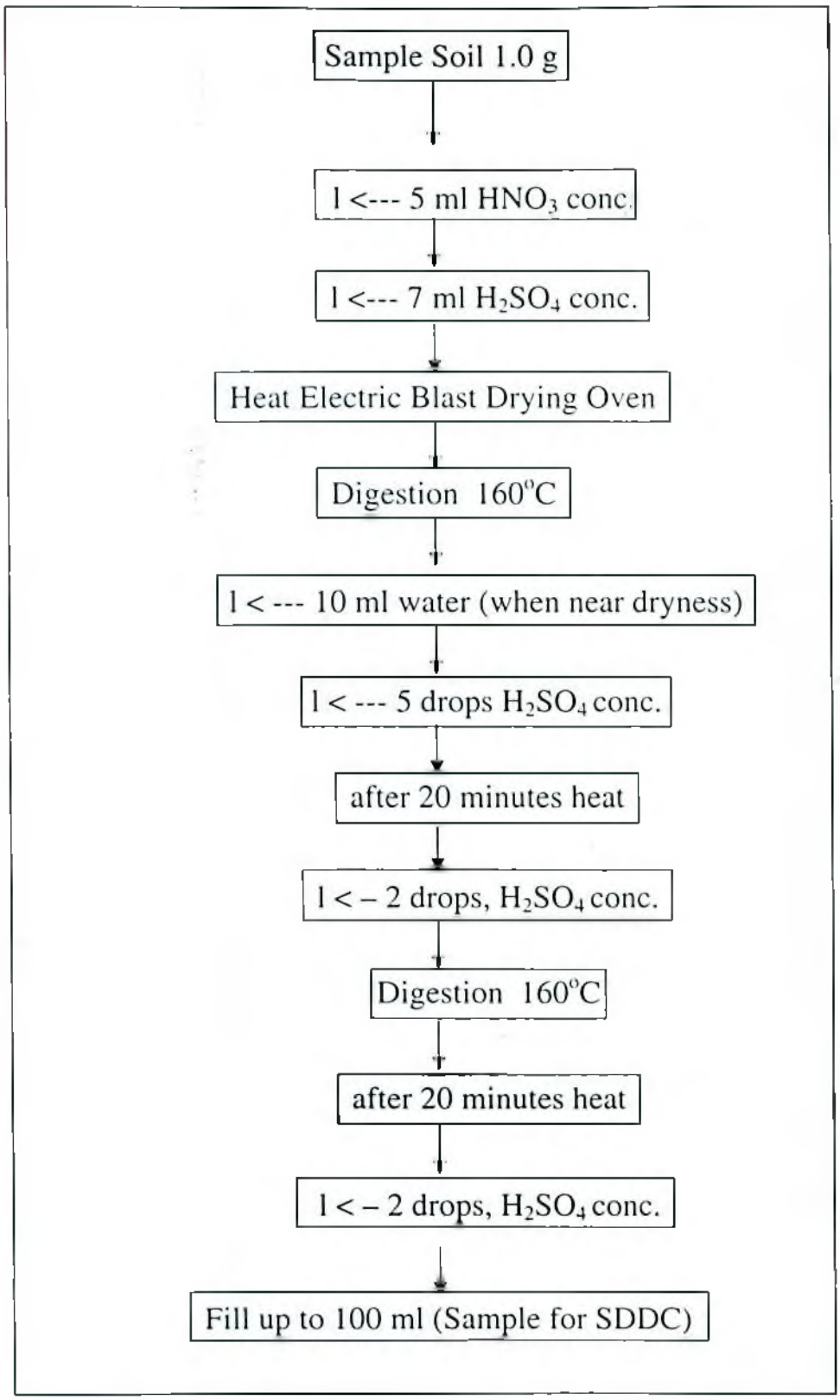
Reagent

HNO_3 concentrated

H_2SO_4 concentrated

and for sulphate Glacial acetic acid

Ammonia



Flow chart of arsenic of Soil

5.8 Data Presentation :

The chemical analysis data (both water and soil) have been presented in graphically on according to the objectives of this study.

Questionnaire for socio-economic situation and arsenicosis diseases problem in the study area was framed after through study of relevant literature and discussion. Tabulation and data processing were analyzed both by manually and mechanically software in computer. **Per cent** distribution, and **cartographic techniques** were used for different variables.

CHAPTER SIX

6. RESULT AND DISCUSSION

6.1. Introduction

Results of chemical analyses of soil and water of tubewells in the months of March and June (2001) has been presented in this chapter and Health Socio-economic data of the arsenicosis patients has been presented in chapter seven.

6.2. Water

To fulfill the objective of the research to identify the sources of arsenic and other unfriendly toxic elements and compounds which contaminated the groundwater, fifteen samples of sediment taken randomly for the chemical analyses. The chemical analyses done for those materials are arsenic, iron, calcium, chloride, magnesium, sulfate and nitrate. The results of the chemical analyses have been plotted (except soil) in the graph sheet along with plotting permissible limit of those elements in drinking water by the World Health Organization and Bangladesh Department of Environment standard.

The results are discussed below:

Results of Chemical Analyses of Sediments, Water of tube wells in the months of March and June (2001)

Table-6.1: Water Analysis of 1st Phase Data (Dry Season)

Lab Cod.	PH	Tem. °C	D.O	Bicar	Fe	Ca	Cl	Mg	SO_4	NO_3	As- in Lab.	As- in Field
STW -1	8.3	–	–	7	0.33	15.16	7.5	54.71	0.06	1.6	0.21	0.34
STW-2	8.4	28	3	8	0.33	1.84	7.5	125	0.03	4.8	0.11	0.85
STW -3	8.0	28	3.2	6	0.67	10.95	6	93.87	0.15	5.77	0.06	0.65
STW -4	8.0	24	1.7	10	0.33	9.26	12	23.64	0.18	1.87	0.08	0.6
STW -5	7.7	–	–	13	0.16	25.26	4.5	24.16	0.15	0.035	0.03	0.45
STW -6	7.4	–	–	10	0.16	21.05	9	8.17	0.12	0.67	0.03	0.25
STW -7	8.4	–	–	14	0.67	24.42	7.5	28.57	0.03	6	0.03	0.85
STW -8	6.9	–	–	10	0.33	29.47	10.5	35.26	0.06	1.4	0.03	0.8
STW -9	8.2	–	–	15	0.33	45.47	9	38.21	0.03	0.37	0.03	0.08
STW -10	8.3	–	3.2	17	0.16	26.1	6	62.2	0.15	2.6	0.06	0.65
STW -11	7.5	–	–	20	0.16	43.78	9	32.9	0.12	2.8	0.06	0.9
STW -12	7.4	30	2.7	36	0.33	26.94	136.5	50.46	0.15	4.17	0.13	0.3
STW -13	7.3	–	2.5	54	0.33	33.68	13.5	22.45	0.03	0.67	0.09	0.55
STW -14	8.3	28	2.4	26	0.33	62.31	16.5	114.34	0.06	4.6	0.08	0.1
STW -15	8.3	–	2.9	25	0.33	11.79	34.5	31.87	0.15	2.37	0.06	0.08
STW -16	8.4	34.8	1	24	0.33	39.57	19.5	27.65	0.03	0.47	0.08	0.01
DTW 17	7.8	–	5.8	10	0.33	33.68	145.5	61.49	0.06	4.4	0.08	0.01
DTW 18	8.0	24	1.7	15	0.33	24.42	10.5	13.44	0.003	2.33	0.09	0.005
19					0.33	34.52	7.5	49.26	0.03	5.93	0.2	
20					0.33	39.57	16.5	19.35	0.12	1.13	0.06	
21					0.33	26.94	6	21.18	0.03	0.83	0.06	
22					0.67	42.94	24	34.38	0.06	6.57	0.13	

Table-6.2: Water Analysis of 2nd Phase Data (Wet Season)

Lab Cod.	pH	Tem °C	D.O.	Bi-carb	Fe	Ca	Cl	Mg	SO_4	NO_3	As-in Lab.	As-in Field
1	7.6		25	9	0.33	51.3	817.5	222.8	0.031	2.5	0.07	
2	7.5		30	7	0.33	47.15	33	252.4	0.031	2.67	0.1	
3	7.4		18	13	0.5	34.52	81	223.9	0.031	4.6	0.15	
4	8.5		10	18	0.33	40.5	100.5	238.3	0.031	4.33	0.06	
5	7.5		15	12	0.33	50.52	35	234	0.031	2.33	0.08	
6	7.6		15	6.2	0.17	45.47	84	244.6	0.06	0.17	0.08	
7	7.3		12	6.3	0.5	39.57	49.5	117.3	0.003	2.8	0.16	
8	7		22	12	0.33	69.04	49.5	345.8	0.003	3.53	0.17	
9	7		21	19	0.17	63.15	34	98.5	0.31	5.39	0.2	
10	7.2		15	8	0.5	33.68	34.5	42	0.18	5.7	0.24	
11	7.4		21	4	0.33	52.2	43	161.8	0.03	5.4	0.42	
12	7.1		22	10.9	0.5	39.57	73.5	221.3	0.15	1.1	0.13	
13	6.8		35	4	0.67	82.52	816	326.2	0.18	5.8	1.33	
14	6.8		13	10.5	0.33	13.47	42	66.4	0.31	5.53	0.14	
15	6.7		23	15	0.83	5.05	79.5	67.4	0.18	5.63	0.2	
16	7.4		22	18	0.33	35.1	108	70.1	0.31	2.67	0.14	
17	8.4		10	19	0.33	32.84	51	118.1	0.03	1	0.15	
18	7.3		11	4.9	0.33	40.42	85	111.2	0.03	1.06	0.16	

P^H : In both the seasons , the P^H value of tubewell's is below the WHO as well as Bangladesh permissible limit. It appears that during dry season, the P^H becomes lower than in the wet season. The highest pH value is 8.4 which appears in sample no. 16 (dry season) and sample no. 17 (wet season). Both samples are inside the polder.

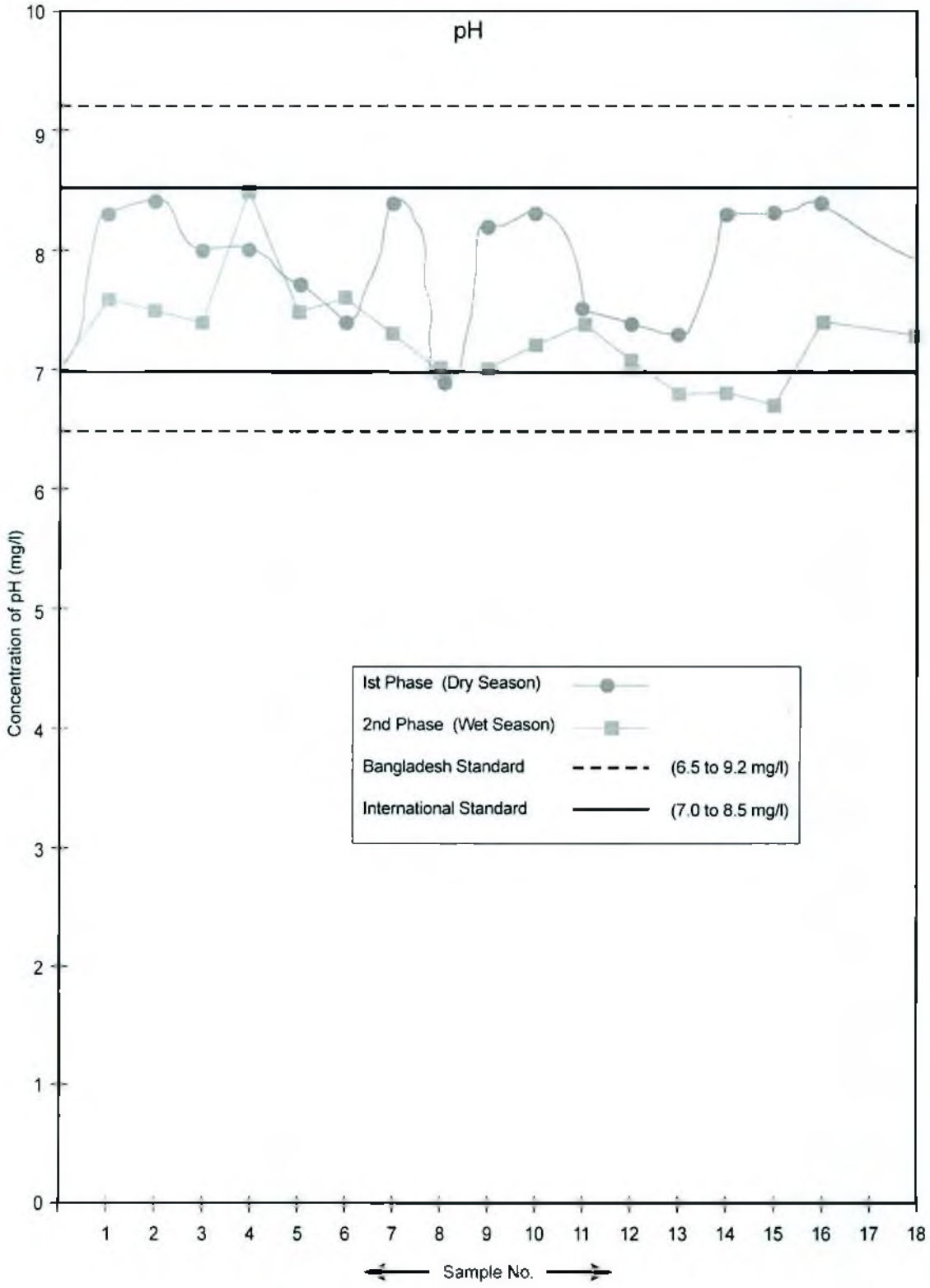


Figure-6.1 : Showing the Existence of pH in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season.

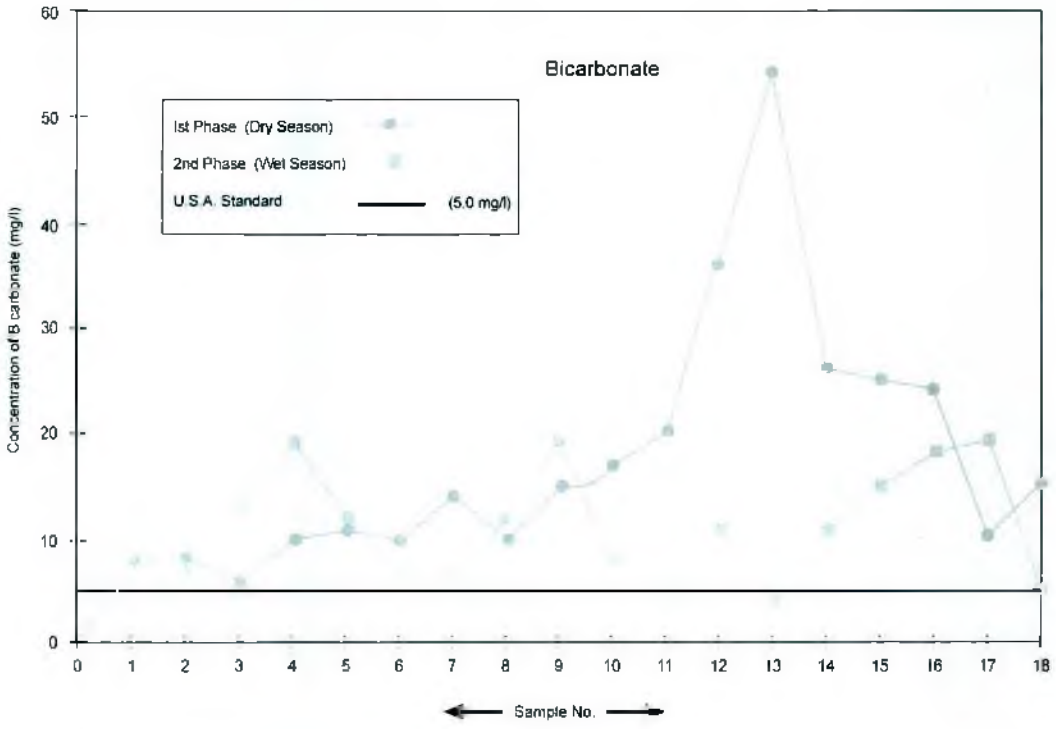


Figure-6.2 : Showing the Existence of Bicarbonate in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season.

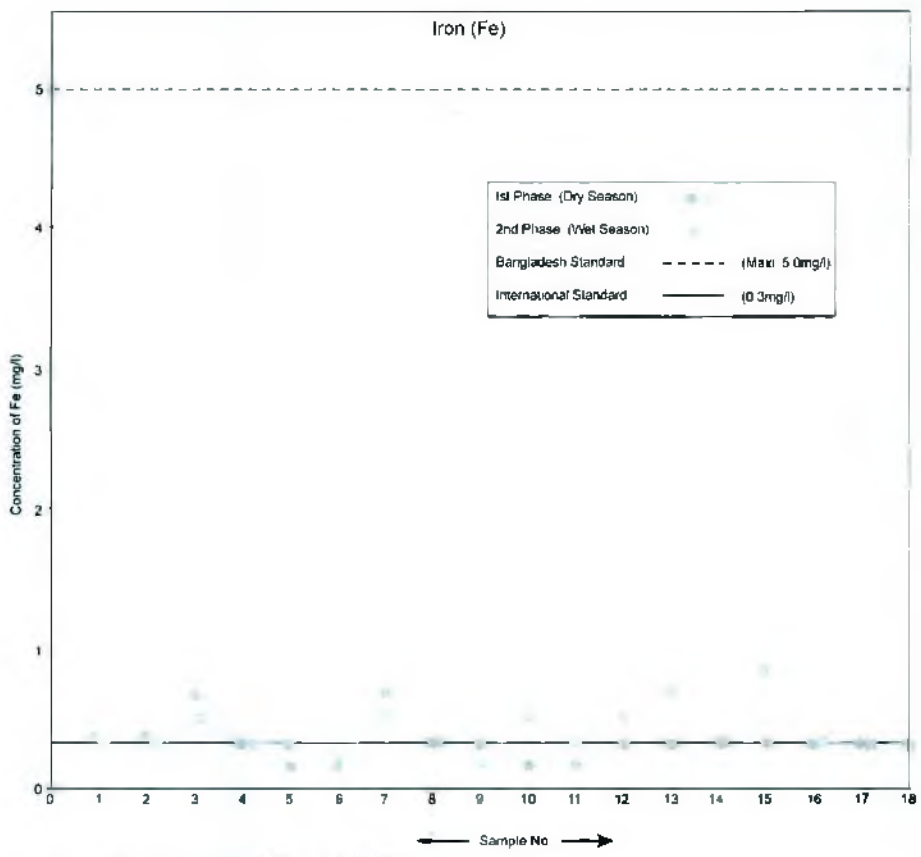


Figure-6.3 : Showing the Existence of Iron in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

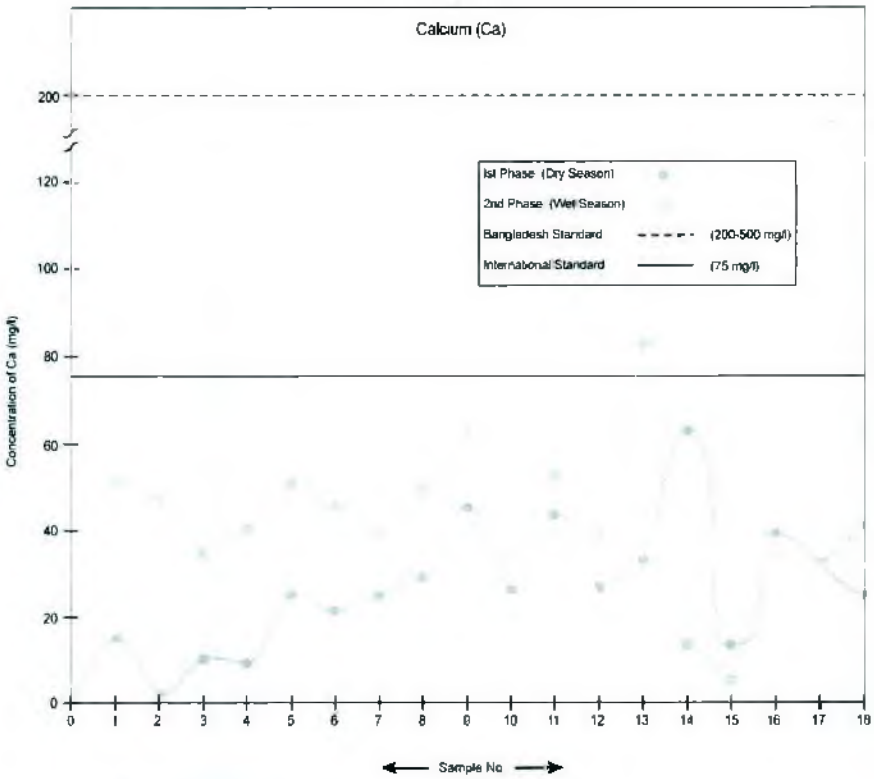


Figure-6.4 : Showing the Existence of Calcium in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

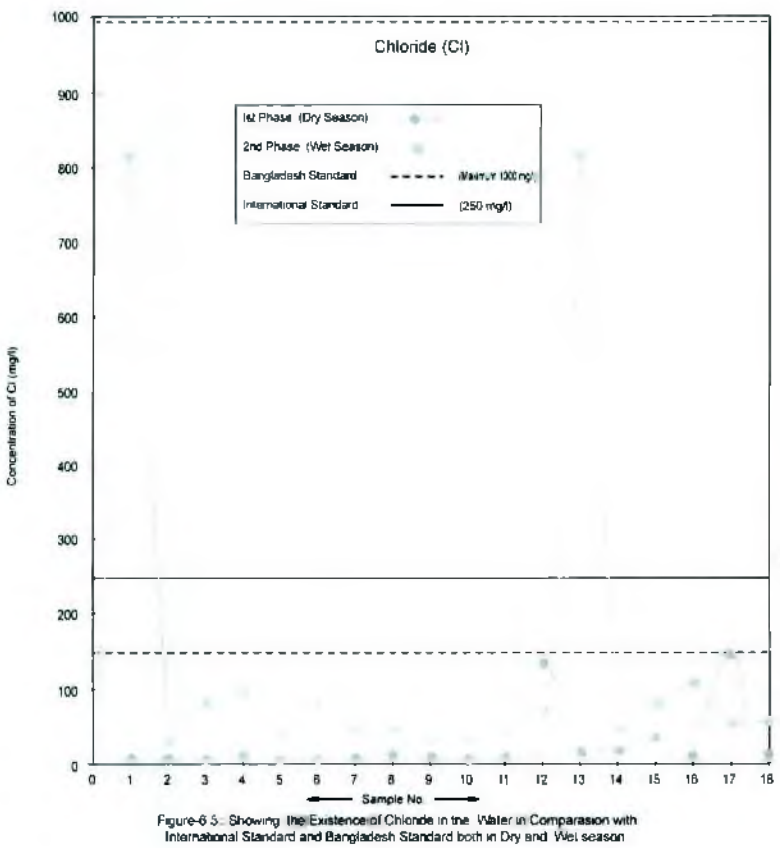


Figure-6.5 : Showing the Existence of Chloride in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

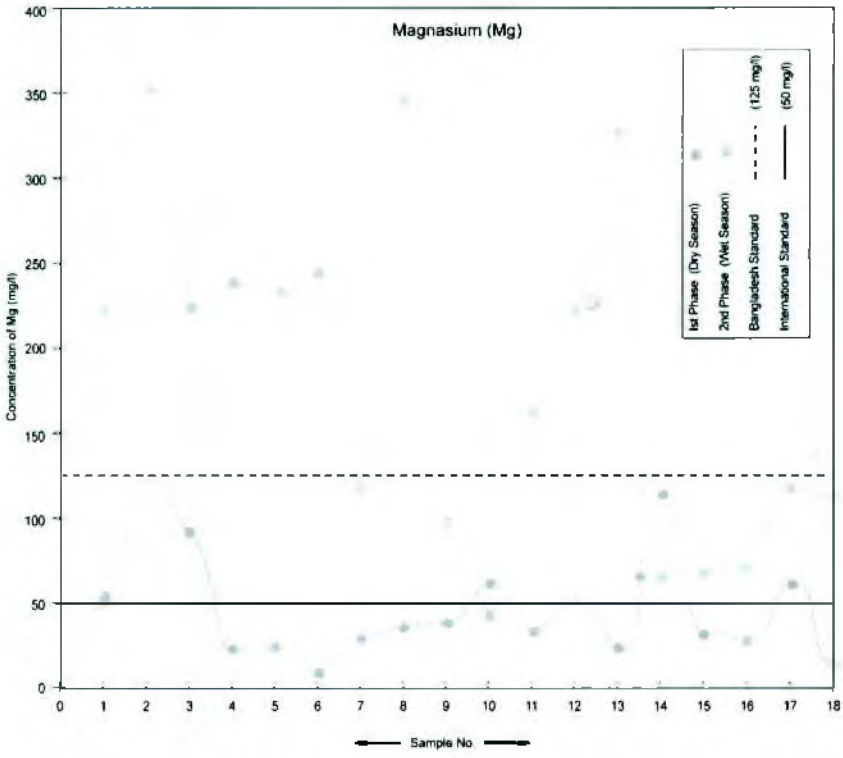


Figure-6.6 : Showing the Existence of Magnasium in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

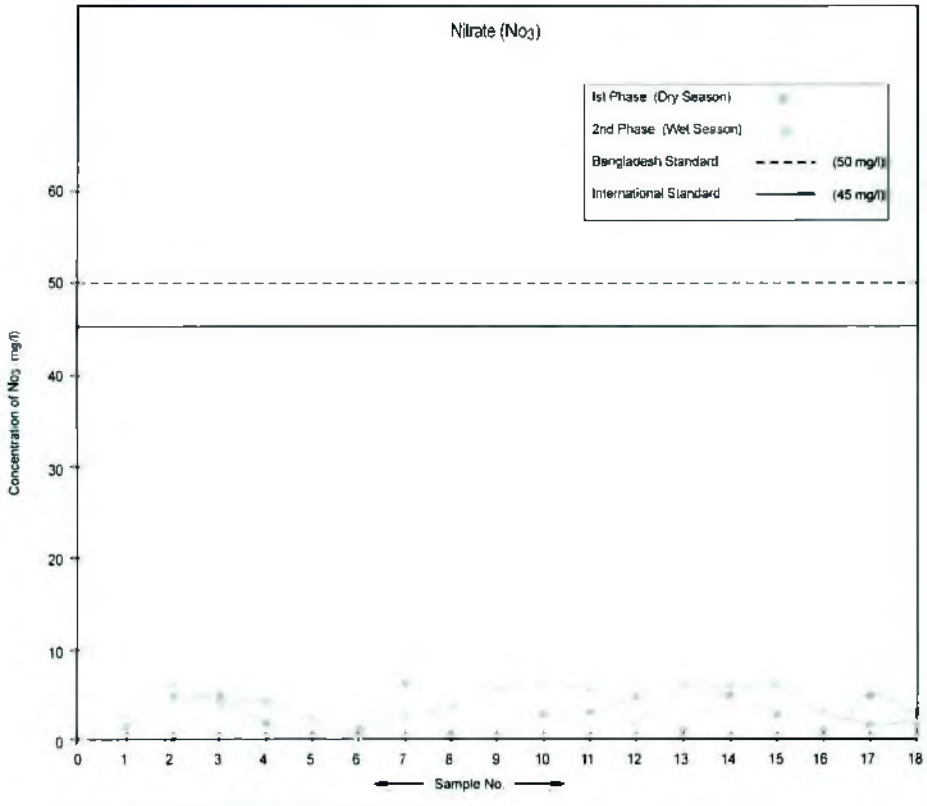


Figure-6.7 : Showing the Existence of Nitrate in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

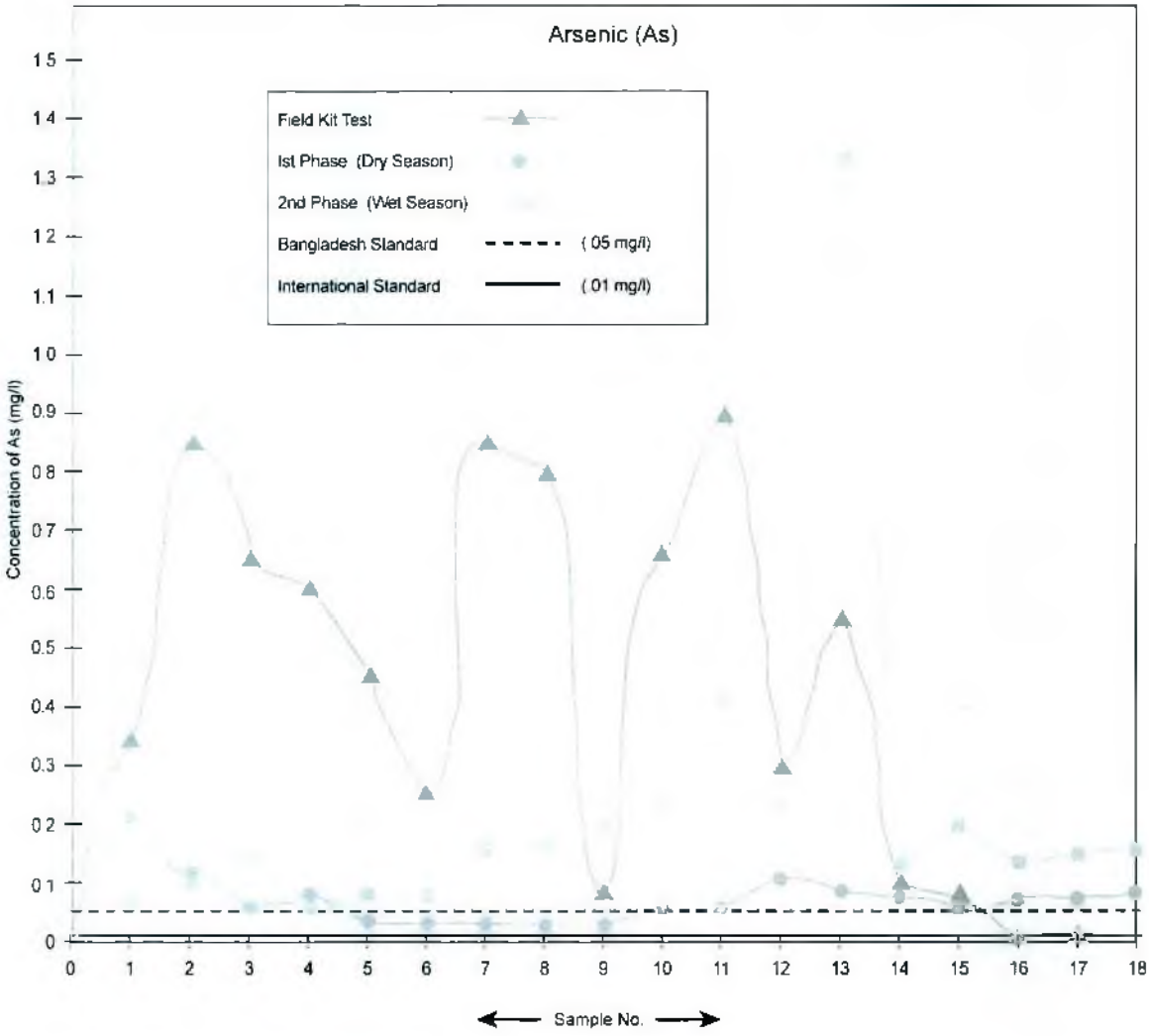


Figure-6.8 : Showing the Existence of Arsenic in the Water in Comparasion with International Standard and Bangladesh Standard both in Dry and Wet season

Temperature: The records do not give any indication of increase or decrease of temperature of groundwater. On one deep tubewell shows higher temperature. But it is not common case even in one shallow tubewell well there higher temperature. The temperature ranges from 22° to 30°C. There is relation of solubility of amorphous variety of arsenic with the temperature. Arsenic oxide exist in three forms; (i) an amorphous glass, s.g 3.7 to 3.8 m.p. 2000 (ii) octahedral (the common form), s.g. 3.089, m.p. 2750 bp <650 and (iii) monoclinic s.g. 3.85 m.p. about 3120. The solubility (1 part in about 25 parts of water at 13°, or in 12 parts at 100 °C) decrease on standing. Owing to conversion to octahedral form ranges from (Paerington, J.R. 1961). And the solubility of octahedral from ranges from g./100 g. of water (1.21, 1.65, 2.05, 2.03, 4.45 and 8.18 at temperature 0°, 15 °, 25 °, 39.8 °, 62 °, 98.5 ° respectively). Under the temperature condition if the arsenic is prevailing either in amorphous or octahedral variety, there is possibility of dissolving the arsenious material in the ground water.

Dissolved Oxygen (D.O.): The dissolved oxygen measured shows the water in the deep wells have less D.O. than those in the shallow wells, which ranges from 1 to 9 (appendix-B). But comparative study does not show any relation with the increase or decrease of arsenic concentration.

Bicarbonate: In the wet season water in 3 tubewells remains within permissible of USA standard but in the dry season, in all the 16 wells the bicarbonate content higher than the permissible limit. It appears that during the dry season the 8 wells became higher.

Iron : In the wet season , water in 2 out of 18 tube tubewell swells remains within WHO permissible limit but according to Bangladesh permissible limit

water in all the tubewells are within the Bangladesh permissible limit. In the dry season , water in 4 tubewells has higher content of iron than the WHO standard and water in all the tubewells wells remain within the Bangladesh standard. It is observed that during dry season the concentration of iron becomes higher than in the wet season.

Calcium: From the results, it appears that in only one tubewell water the content of Ca is beyond WHO permissible limit (appendix-B). And both the seasons, water in all the tubewells remain within the Bangladesh standard (appendix-B). During dry season the concentration of Ca becomes higher than in the wet season.

Chloride: In the dry season the content of chloride in all the tube wells remains within the WHO and in Bangladesh permissible standard. But in the wet season, the content of chloride becomes higher in all the tubewells and in 2 tube wells it becomes high but remains within the Bangladesh permissible limit. In the dry season, the concentration of chloride becomes higher than in the dry season.

Magnesium: WHO permissible limit of magnesium is 50 ppm while that of Bangladesh is 125 ppm. It appears from the result the during the dry season only one tubewell water is within the WHO permissible limit. And according to Bangladesh permissible limit 8 tubewell water are drinkable. In the wet season 15 out of 20 tubewells have Mg content within WHO standard and according to Bangladesh standard water in all the tubewell remain within the Bangladesh Standard (appendix-B). It is observed that during dry season the concentration of Mg becomes higher.

Sulphate : Results show that water in all the tubewells are well below the permissible limit of WHO and Bangladesh standard.

Nitrate: On both the seasons, content of nitrate in all the tubewell water remains within the WHO as well as the Bangladesh permissible standard. However, during dry season in 11 tubewell water the content of nitrate becomes higher than in the wet season.

Arsenic: The permissible limit of arsenic content in water on WHO standard is 0.01 ppm and that in Bangladesh standard is 0.05 ppm. From the results obtained in the study, water in all the tubewells contains high contents of the metal and in the dry season and only in 5 tubewells the water is within the permissible limit, which is really alarming. In the dry season water in all the tubewells exceeds both the WHO as well as the Bangladesh permissible standard. During dry season the concentration of arsenic becomes very high than in the wet season.

6.2.1. Comparison with field kit test results and laboratory test results of arsenic:

Groundwater is the main source of drinking water for the people of Bangladesh, with over 95 percent of the population are consuming groundwater from tubewells. But all of time tubewells' water are drinkable. Water is tainted by arsenic and the arsenic problem in Bangladesh is rapidly spreading, the arsenic contaminated tubewells need to be identified as soon as possible so that people can be prevented from taking arsenic contaminated water. The test for arsenic in water can be done by very sophisticated laboratory based techniques (spectrophotometric technique) or by a simple field kit technique.

Kit and SDDC (spectrophotemetric) methods were used for analysing some samples from Ramganj, Lakshmipur district. Kit method showed less than Bangladesh guideline value of 0.05 mg/l and WHO guideline value of 0.01 mg/l or more than 0.05 mg/l and 0.01 mg/l of arsenic whereas, SDDC method showed less than Bangladesh guideline value and more than WHO (International) guideline value of arsenic. It was also less than U.S.A. standard value (0.05 mg/l) of arsenic. This preliminary finding showed that kit could serve as a first screening of the samples and the laboratory method (spectrophotometric) will reveal the exact level of arsenic contents of the samples.

Eighteen samples (100 per cent) of different locations of Ramganj, Lakshmipur were analyzed by SDDC spectrophotometric method and found that only five samples contain less than 0.05 mg/l arsenic. The arsenic contains of other samples were more than Bangladesh and International (WHO) guideline values. From the result it is seen that the accuracy and precision of Field Kit and Laboratory methods are significantly different. We can say as a cause that Field Kit Test Method was not a reliable method. In this method, the colour on the strip was compared to the colour chart (attached with the strip box) corresponding to concentration ranges provided. Colour matching is not so easy as we are think. So this method may provide wrong result.

On the other hand, laboratory based analysis needs long procedure to prepare water samples before analysis with spectrophotometer and skilled and trained personnel to operate. Excepting this procedure, it may risk of obtaining false negative or positive result. Besides, sunlight heat, sample shaking to bring in laboratory, long time to put off in laboratory are also risk of getting false negative or positive results.

For the above causes, Field Kit Test result was high or positive and laboratory method result was less or negative.

Table-6.3: Shows the number and percentage of wells tested by both Field-kit method and laboratory analysis.

	By the Field-kit		In the laboratory	
	<0.05 mg/l	>0.05 mg/l	<0.05 mg/l	>0.05 mg/l
No. of well tested	08	43	05	17
Percentage	15.7	84.3	22.7	77.3

During the period of field study three teams were working for testing water samples from the shallow and deep tubewells for the determination of arsenic, temperature, dissolved oxygen, P^H and bicarbonate and noted the lithology of the tubewells. In this time, 60 tubewells were tested. Nine samples result was dropped for its vague result. All these tests were done using Analytical Test Strips Method (Field-kit). Among these tested tubewells, 22 samples tested in the laboratory. Finally 18 samples were considered for comparison of laboratory results with Field-kit results. Due to various problem other 4 laboratory tested results were not considered in this issue.

The field-kit is a very suitable one for a quick assessment of the sampling strategy. It helps to obtain an idea about the pattern of distribution with contaminated and non-contaminated zones. The Field-kit is also very

reasonable to checkout the contaminated tubewells in rural areas for mass people at low cost.

6.2.2. Relationship of Arsenic with Different Parameters:

Arsenic was released due to the oxidation of arsenic-rich pyrite in the aquifer sediments as an ingression of atmospheric oxygen in response to a lowering of the water table by large abstraction over the last decades. However, later on, several detail research-works on the issue dismissed the previous theory. The alternative theory proposes that Arsenic derive from the reductive dissolution of Arsenic-rich iron oxyhydroxides, which in turn are derived from weathering of base-metal sulphides (Nickson et.al., 1998). This theory seems more logical and consistent, with was based on the following facts:

Well waters containing Arsenic always contain low dissolved oxygen (<20 per cent).

Arsenic is almost exclusively found in the absence of nitrate.

Arsenic and Bicarbonate show a positive correlation.

Consistence of low sulphate concentration, whilst Arsenic is higher.

Strong positive correlation between iron and arsenic both in groundwater and aquifer sediments.

The above correlation among different parameters have also been compared various study area by different researchers. However, the above relationships along with others in this study area are described in the sections following.

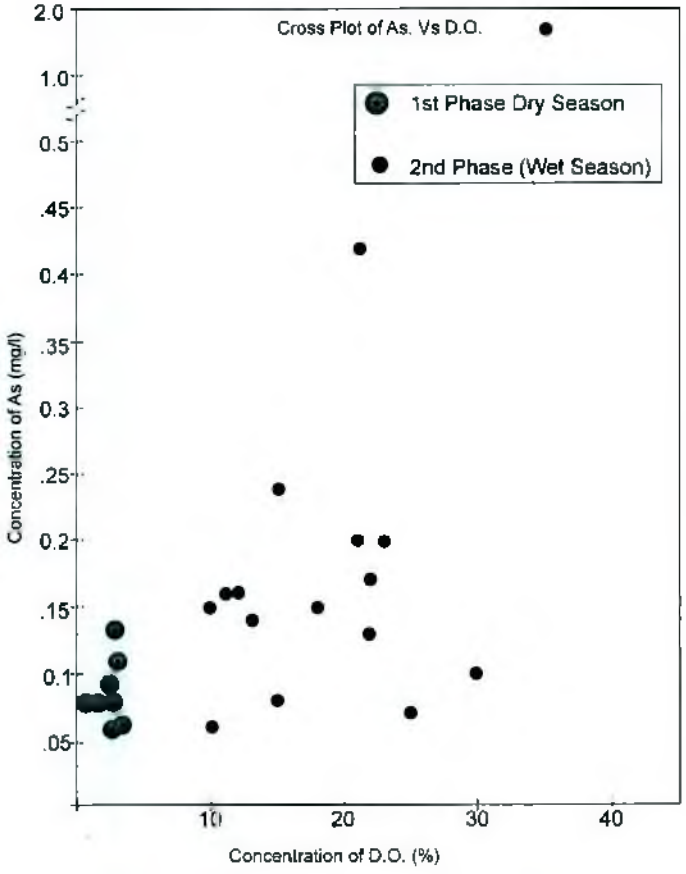


Figure-6.9: Relationship of Arsenic With Dissolved Oxygen

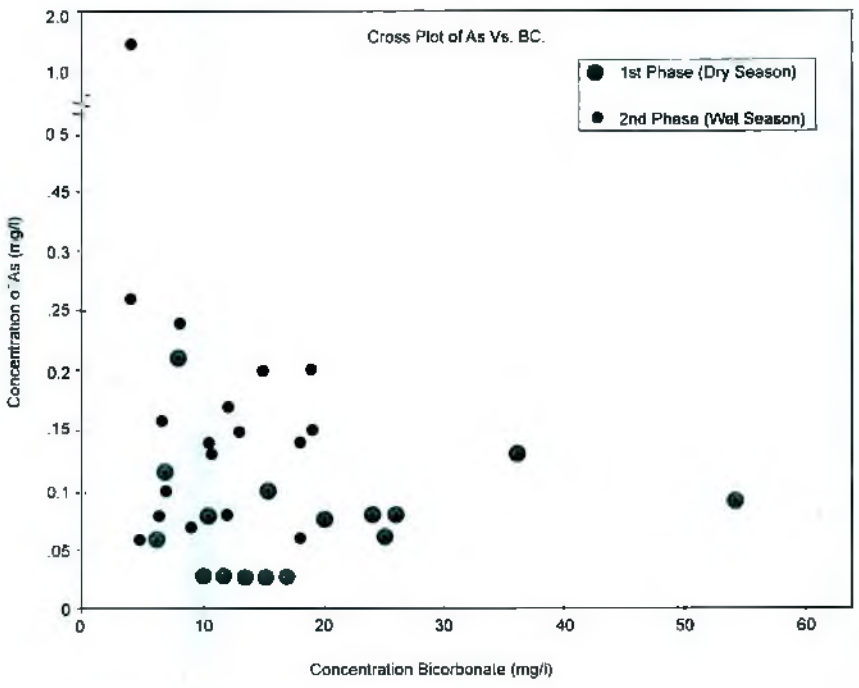


Figure 6.10: Relationship of Arsenic with Bicarbonate

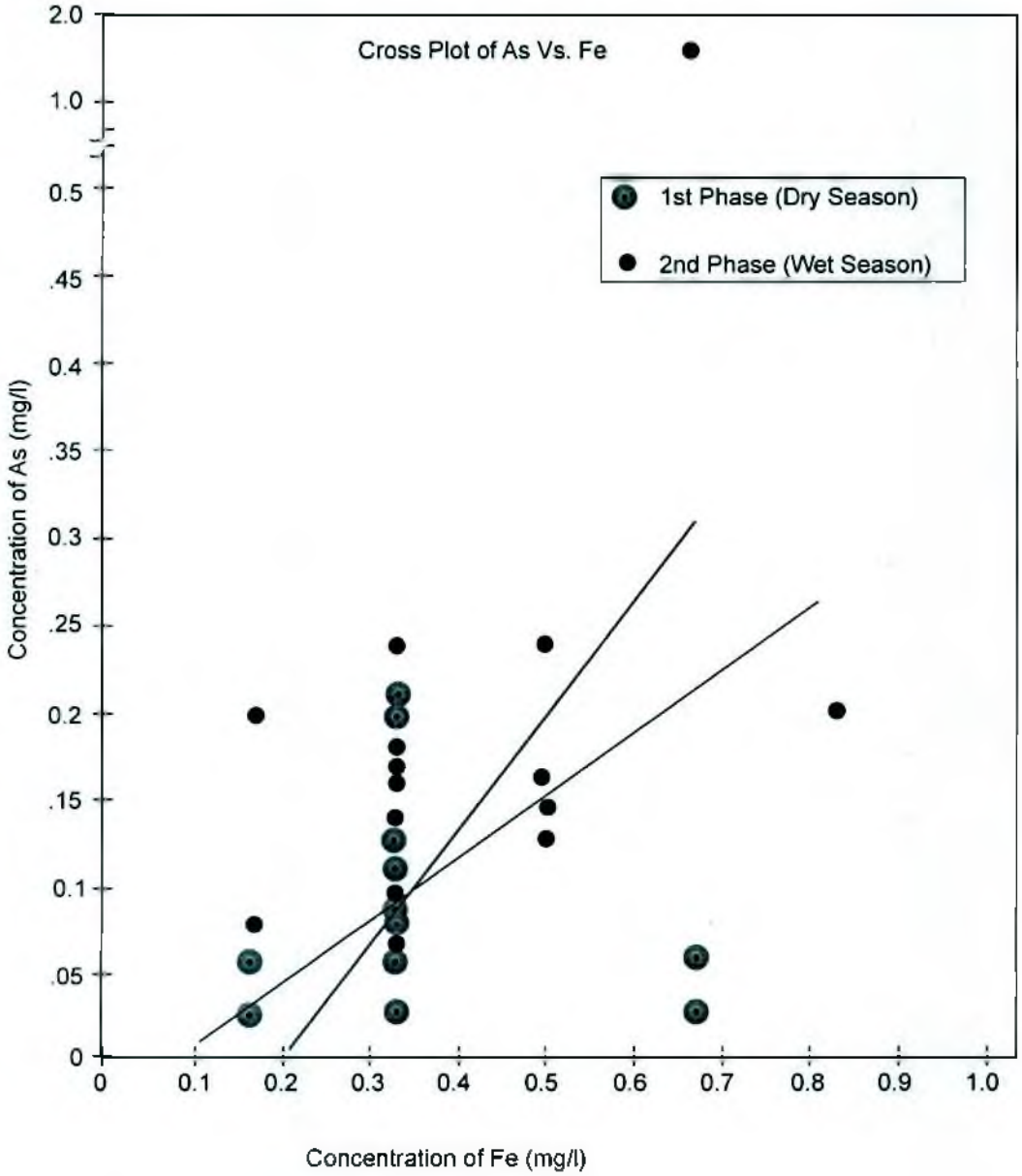


Figure-6.11: Relationship of Arsenic with Iron

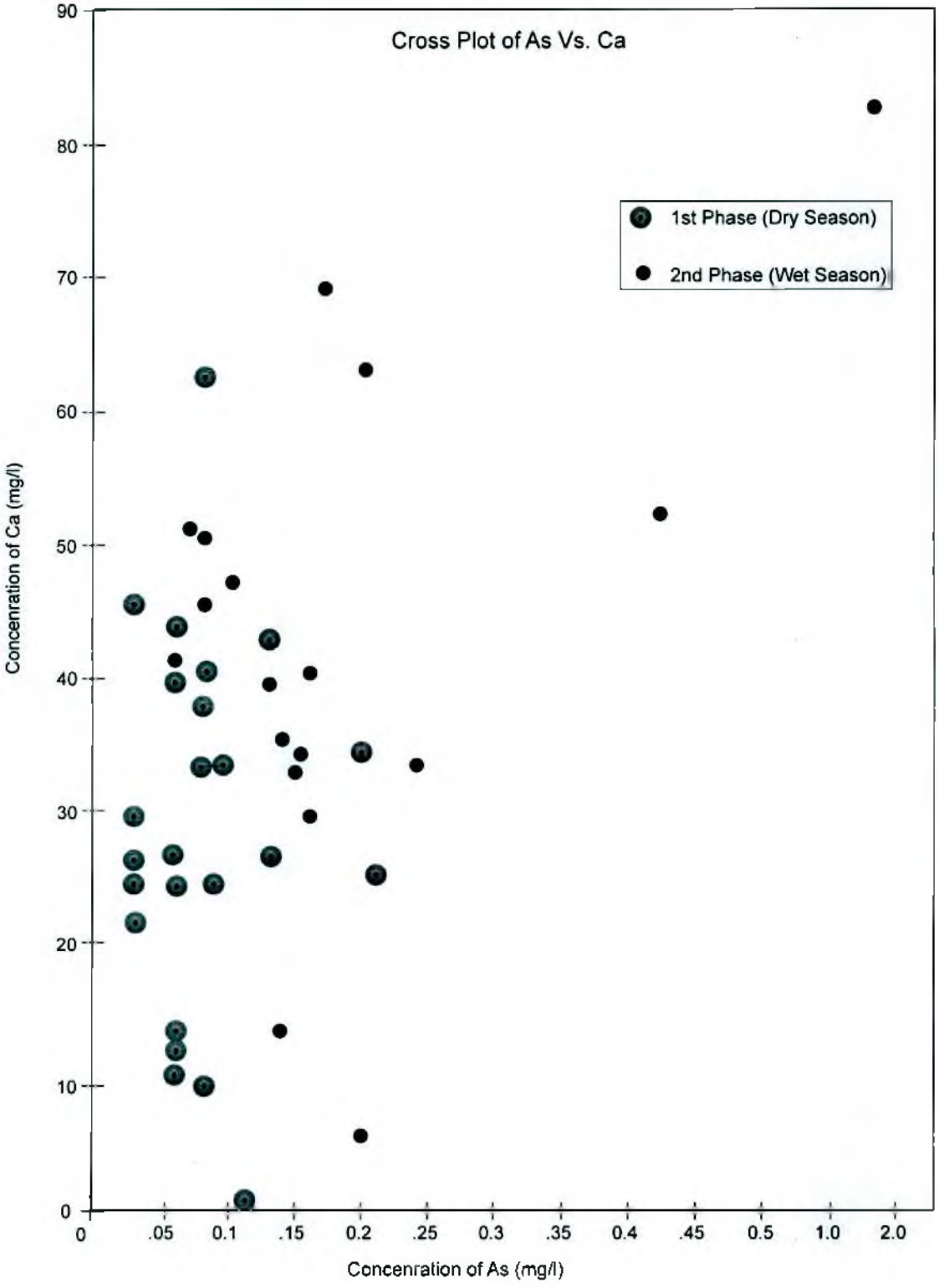


Figure-6.12: Relationship of Arsenic with Calcium

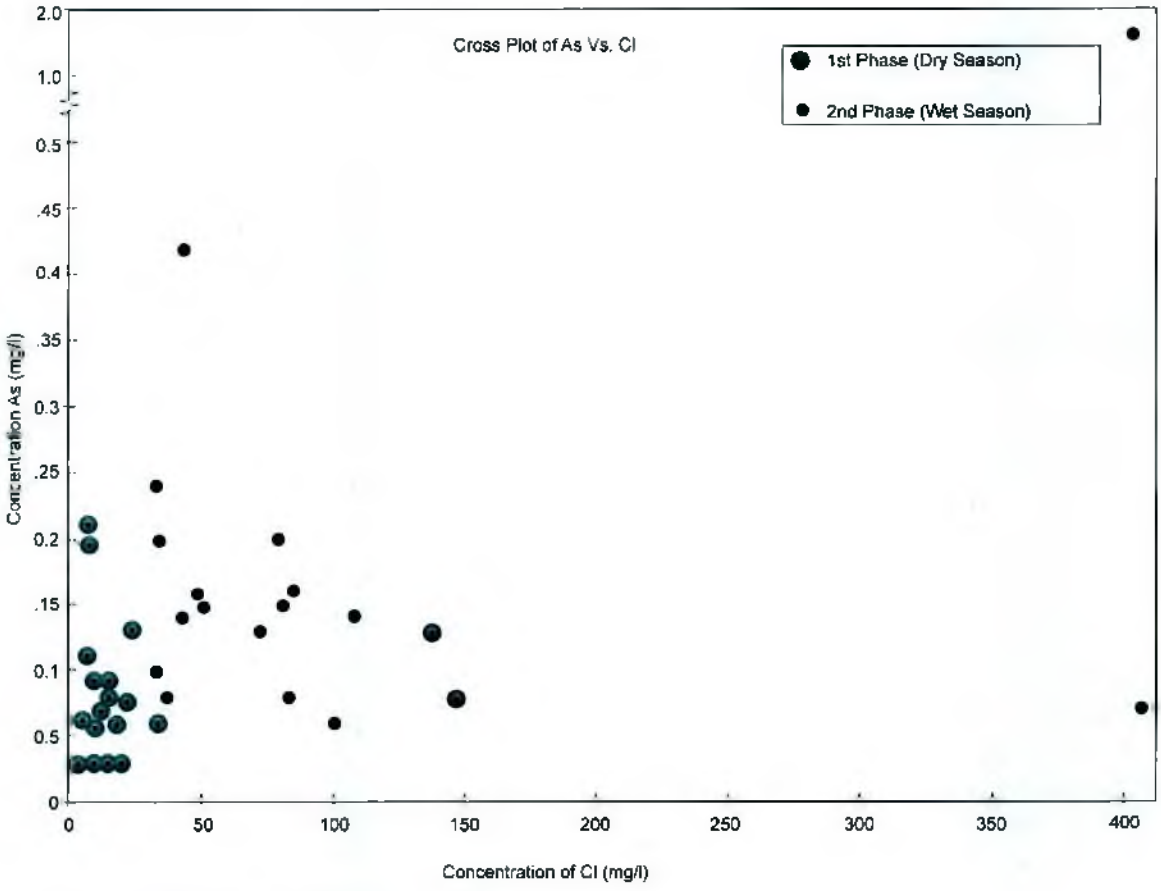


Figure-6.13: Relationship of Arsenic with Chloride

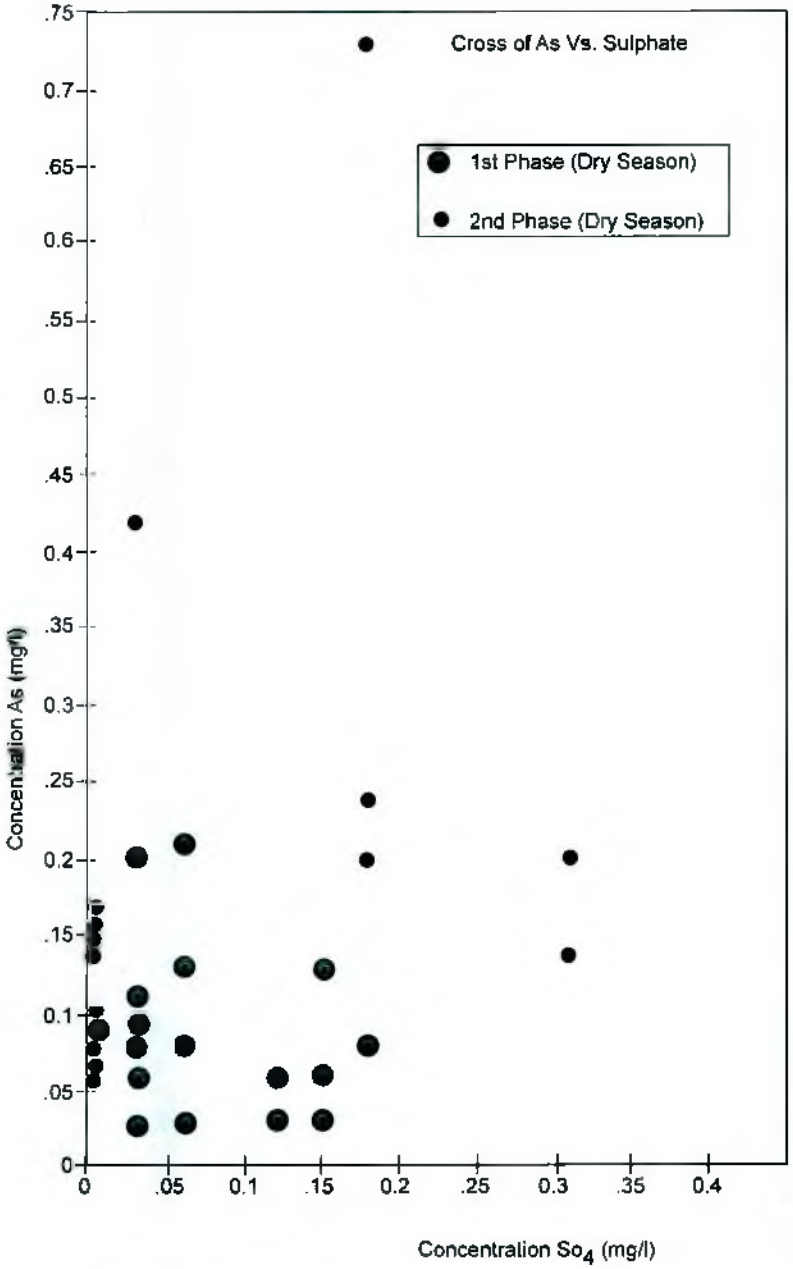


Figure-6.14: Relationship of Arsenic with Sulphate

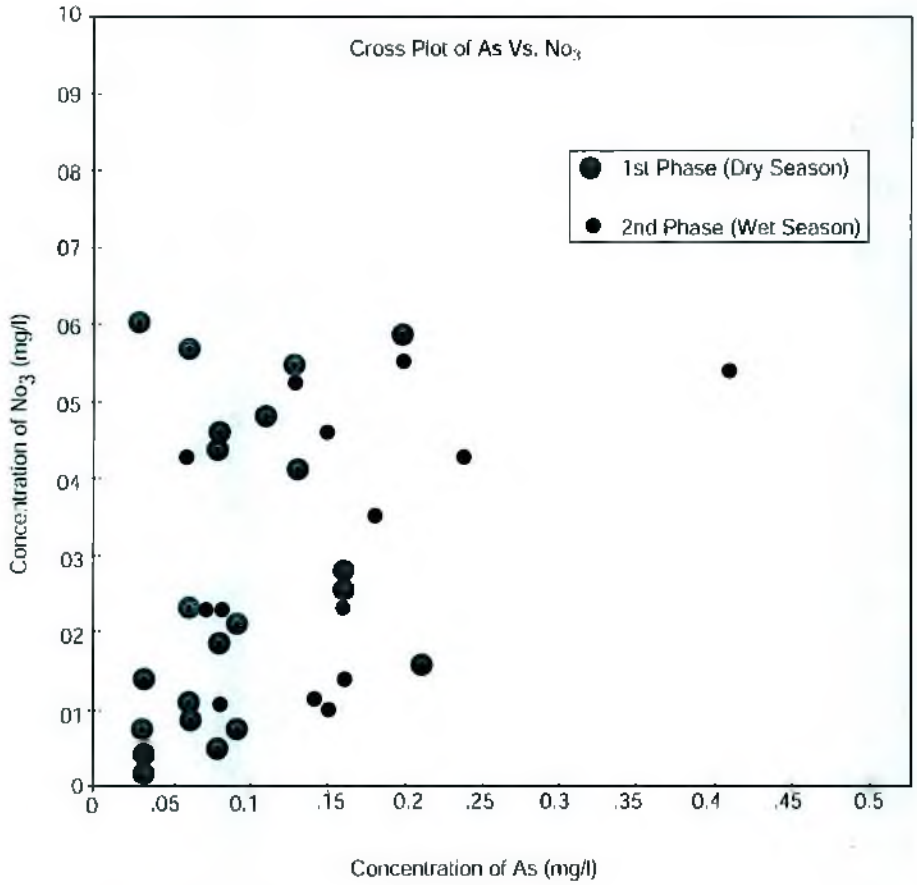


Figure-6.15: Relationship of Arsenic with Nitrate

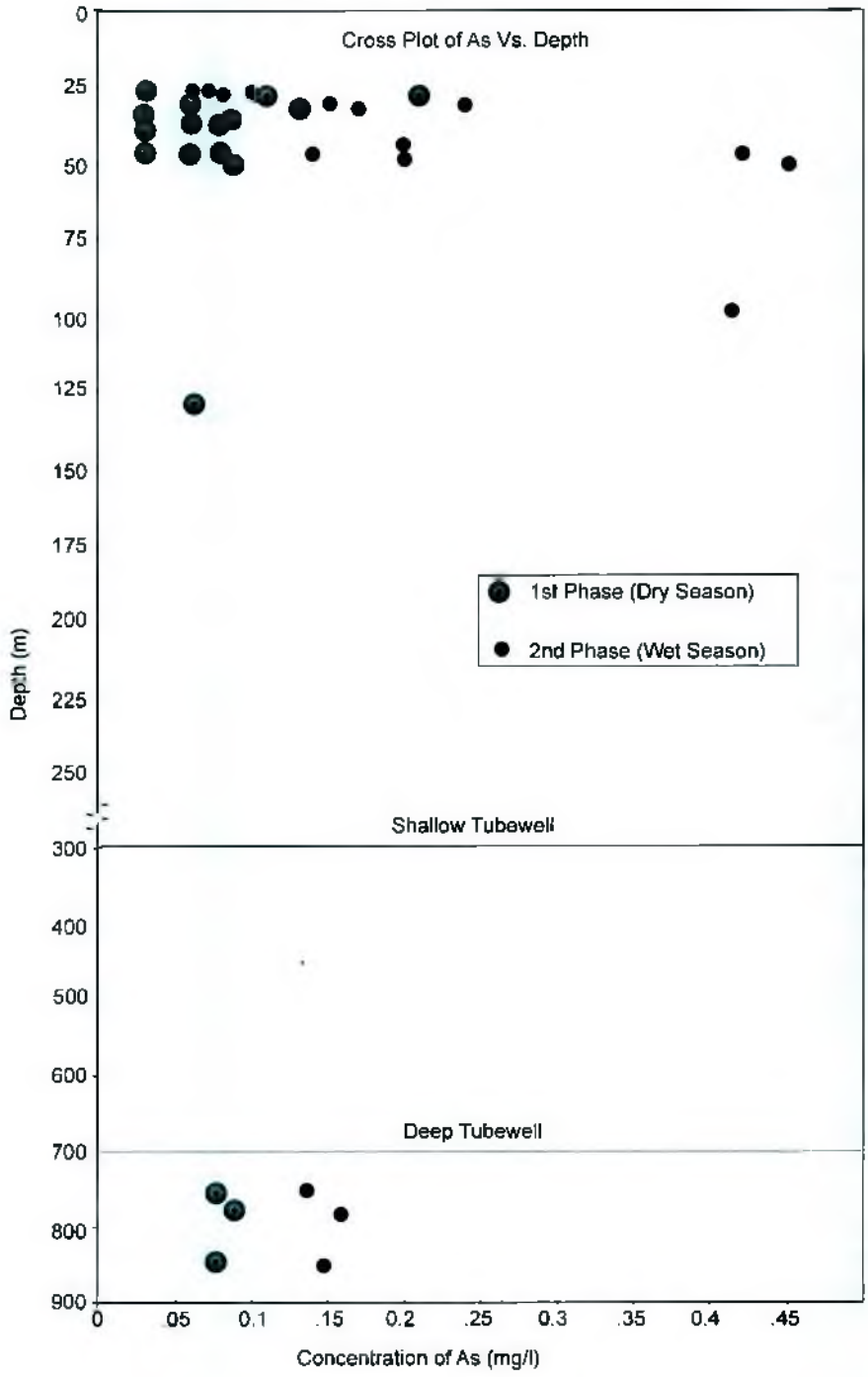


Figure- 6.16 : Relationship of Arsenic with Depth (m) of the Tubewells

Arsenic and Dissolved Oxygen:

There are many disadvantages in distributing water low or high (6-20 per cent) in dissolved oxygen. From the figure (Fig. 6.9) it is clear that tubewell waters containing arsenic above 50 ppb and 10 ppb (The Bangladesh Government drinking water standards specifics the maximum contaminated level (MCL) for arsenic in drinking water as 50 ppb and WHO guideline for drinking water specifies the MCL for arsenic as 10 ppb), always contain less than 6-7 per cent dissolved oxygen. However, most of the samples showed D.O. (per cent) greater than 10 per cent, which may be due to difficulties in measuring oxygen. According to the theory of Nickson et al., (1998), tubewell waters containing arsenic always contain low dissolved oxygen (<20 per cent). In this study area, this theory was being not applicable.

Arsenic and Bicarbonate:

Arsenic and Bicarbonate show a positive correlation (Nickson, et al., 1998). The cross-plot of arsenic against Bicarbonate (Fig. 6.10) shows a simple correlation. In some cases, we can see with increase of Arsenic, Bicarbonate also increase. As we know that Bicarbonate is a by-product of redox relations, the reducing conditions should therefore be increased with Bicarbonate increment. Thus, arsenic released from iron-oxyhydroxides or organic carbon should be associated with substantial quantities of Bicarbonate (Shahnewaz, 1999).

Arsenic and Iron:

Iron concentration in deep aquifers is generally much lower, but in the shallow aquifers is greatly higher (Kamal and Chowdhury, 2002). Also, the

cross-plot of arsenic concentration against iron concentration (Fig. 6.11) shows a good correlation. This correlation confirmations of Nickson; et al. (1998)'s theory of strong positive correlation between iron and arsenic both in groundwater and aquifer sediments. The major natural source of iron in groundwater of Bangladesh is the iron-rich subsurface and surface sediments (BWDB, 1978, 1990). The scientists of AAN (1999) reported the concentration of arsenic is likely to be increased with increase of iron concentration. It has been found in the study area, yet it is not well condition.

Arsenic and Calcium

The cross-plot of arsenic against calcium (Fig. 6.12) shows a simple correlation that arsenic is much in 20 – 60 ppm/l range. A very few samples show calcium (ppm/l) greater than 60 ppm/l. But less than 70 ppm/l. About all samples show above 10 ppm/l calcium except three samples. Calcium becomes higher due to vertical movement of water in the aquifer. Calcium is gradually high because arsenic is liquefied in calcium.

Arsenic and Chloride

Chloride is generally present at low concentrations in natural surface water (National water quality data bank, 1976). But high in groundwater. The cross-plot of arsenic against chloride (Fig. 6.13) shows positive correlation that arsenic is always high in low chloride regimes. One sample is very high in very low chloride regime.

Arsenic and Sulphate

The concentration of sulphate in most fresh waters is very low. The cross plot of arsenic against sulphate (Fig. 6.14) shows a positive correlation that Arsenic is always found in low sulphate regimes with the exception of two samples where sulphate is high and a case of arsenic is very high. This high sulphate and arsenic could be the result of anthropogenic activities around the samples tubewell. The origin of sulphate in groundwater is the oxidation of arsenic rich pyrite was the cause for the release of arsenic in groundwater, the samples with high arsenic should have large amount of sulphate. It does not support that consistence of low sulphate concentrate, whilst arsenic is higher.

Arsenic and Nitrate

Arsenic is almost exclusively found in the absence of nitrate. Nitrate is dissolved in arsenic. The cross plot of arsenic against Nitrate (Fig. 6.15) shows that arsenic concentration is consistently higher in samples with very low of Nitrate concentration. Arsenic is mainly found in reduced groundwater. Here Arsenic and Nitrate relation is moderately significant.

Arsenic and Depth

The cross-plot of arsenic against the Depth of tubewells (Fig. 6.16) shows a good coreelation. Nickson (1997) have showed a positive correlation of Arsenic with Depth, which emphasized the increment of reducing conditions with depth. In this study area the shallow (>50m) tubewells show high concentration of arsenic and deep tubewell (>900m) show less variability with lower arsenic concentration. This implies that other factors such as

local hydrogeology, geochemistry, etc. might be responsible for the variation of concentration. Arsenic is the most often occurs tubewells screened between 20m and 60m (Ahmed, et al., 2002). In this study, arsenic concentration is high form 26m to 46m depth.

6.2.3. Comparison with inside polder and outside polder results of arsenic :

Since arsenic in groundwater was recognized as a potential threat to human life, much effort has been directed towards ensuring safe drinking water through mitigation techniques or through finding alternative water sources.

Table-6.4: Inside Polder and Outside Polder of Arsenic

	Inside Polder		Outside Polder	
Sl.No.	1st Phase	2nd Phase	1st Phase	2nd Phase
1	0.21	0.07	0.03	0.08
2	0.11	0.10	0.03	0.16
3	0.06	0.15	0.03	0.17
4	0.08	0.06	0.03	0.20
5	0.03	0.08	0.06	0.24
6	0.08	0.14	0.06	0.42
7	0.08	0.15	0.13	0.13
8	0.9	0.16	0.09	1.38
9	0.20	No Data	0.08	0.14
10	0.06	No Data	0.06	0.20

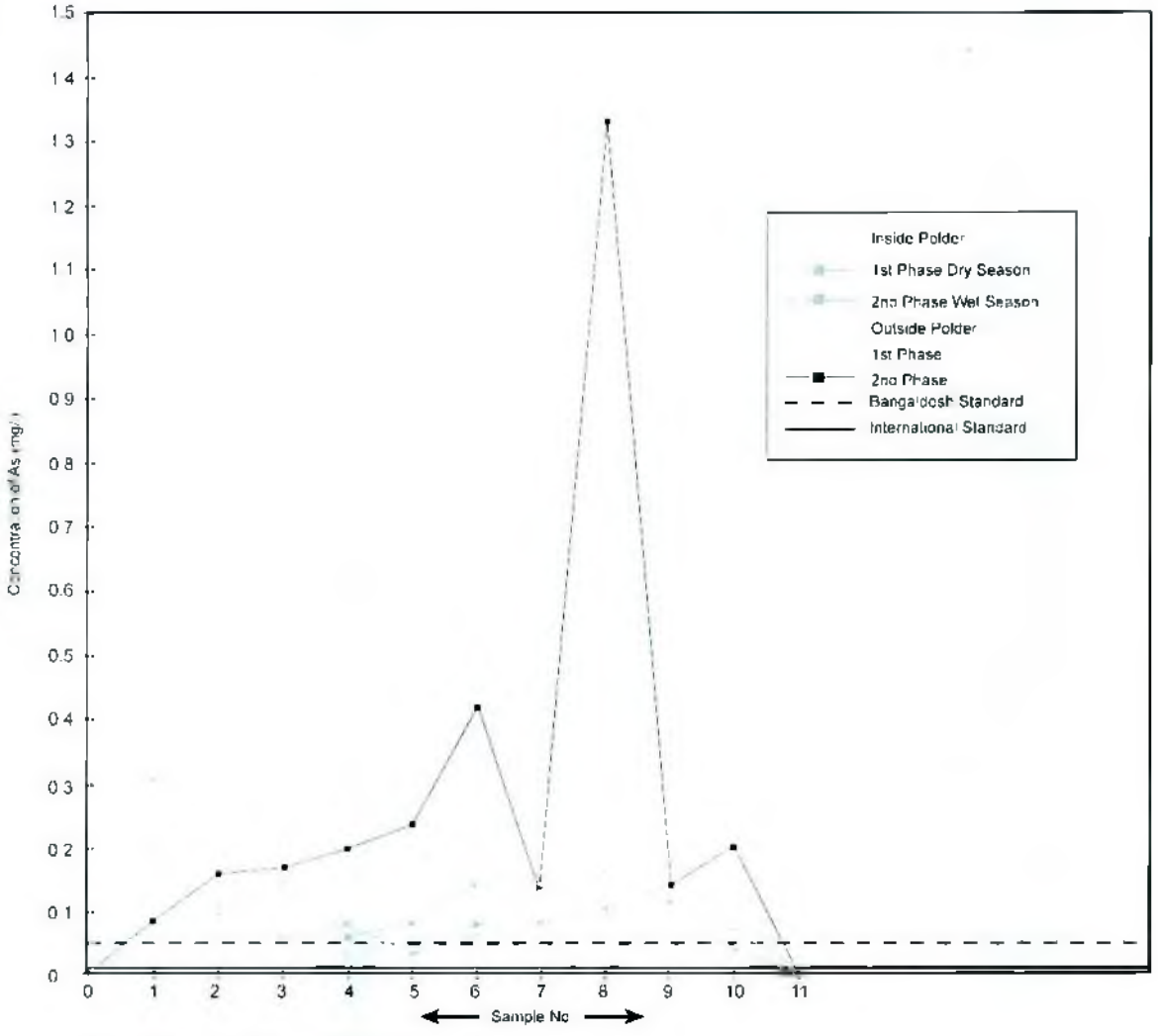


Figure-6.17 : Inside Polder and Outside Polder of Arsenic

In Bangladesh, the main source of drinking water is wells. Almost all the wells are contaminant of arsenic in the study area; Ramganj, Lakshmipur.

The study area is divided into two sides. One side is inside of polder and other side is outside of polder. 10 samples are selected in both sides and both phases.

Arsenic concentration largely depends on water leaching, where water leaching is high, arsenic concentration is low and where water leaching low arsenic concentration is high.

Figure 6.17 shows that all the samples (except two) arsenic concentration in inside polder, in first phase (dry season) is higher than outside polder. Because in outside polder water leaching is more. Water leaching is happened by high tide and low tide or in wet season.

Figure 6.17 also shows that in second phase (wet season), the arsenic concentration of outside polder is higher than inside polder (except three cases). One case is too much excess than other cases. In dry season water leaching is in low. Besides there may have some trap points, where water leaching is very slow or not. This is why in second phase of outside polder, arsenic concentration may be more than in inside polder. It is observed that during wet season content of arsenic becomes higher due vertical movement of water in the aquifer. In an average, arsenic is more in outside polder.

6.3. Soil

The presence of high concentrations of arsenic is not generally dependent on the concentration of arsenic in soils. The constituents and environmental conditions of the soil have a greater influence on arsenic speciation and

mobility than the total concentration in soils. Arsenic in soils is relatively stable at neutral pH and exhibits mobility both at higher and lower pH values.

Table-6.5: Soil

Code	Fe	Ca	Cl	Mg	SO_4	As	NO_3
	ppm/g	%	mg/g	%	ppm	ppm	ppm
01	7.3	6.4	318.75	3.6	0.6	7.33	2.3
02	12.3	2.2	539.06	1.2	0.36	7.33	2.4
03	14.0	1.2	421.87	2.64	0.36	6.67	1.3
04	11.3	1.6	867.13	2.16	0.09	4.33	2.3
05	10.6	17.2	304.60	4.32	0.6	6.0	1.1
06	13.6	5.8	609.37	1.32	0.45	20.33	2.7
07	11.3	4.8	463.75	2.76	0.70	7.67	0.5
08	5.3	1.8	328.12	1.32	0.45	11.67	1.4
09	14.3	3.0	281.25	.96	0.45	7.67	1.1
10	8.3	1.8	585.94	1.08	0.70	12.67	0.4
11	14.6	8.8	140.62	6.0	0.55	2.0	3.3
12	1.0	4.4	231.25	2.16	0.18	9.0	1.3
13	19.3	10.6	562.50	3.6	0.95	6.0	3.0
14	10.6	1.8	257.81	.96	0.5	3.67	1.1
15	15.6	2.6	421.88	.48	0.27	5.0	1.3

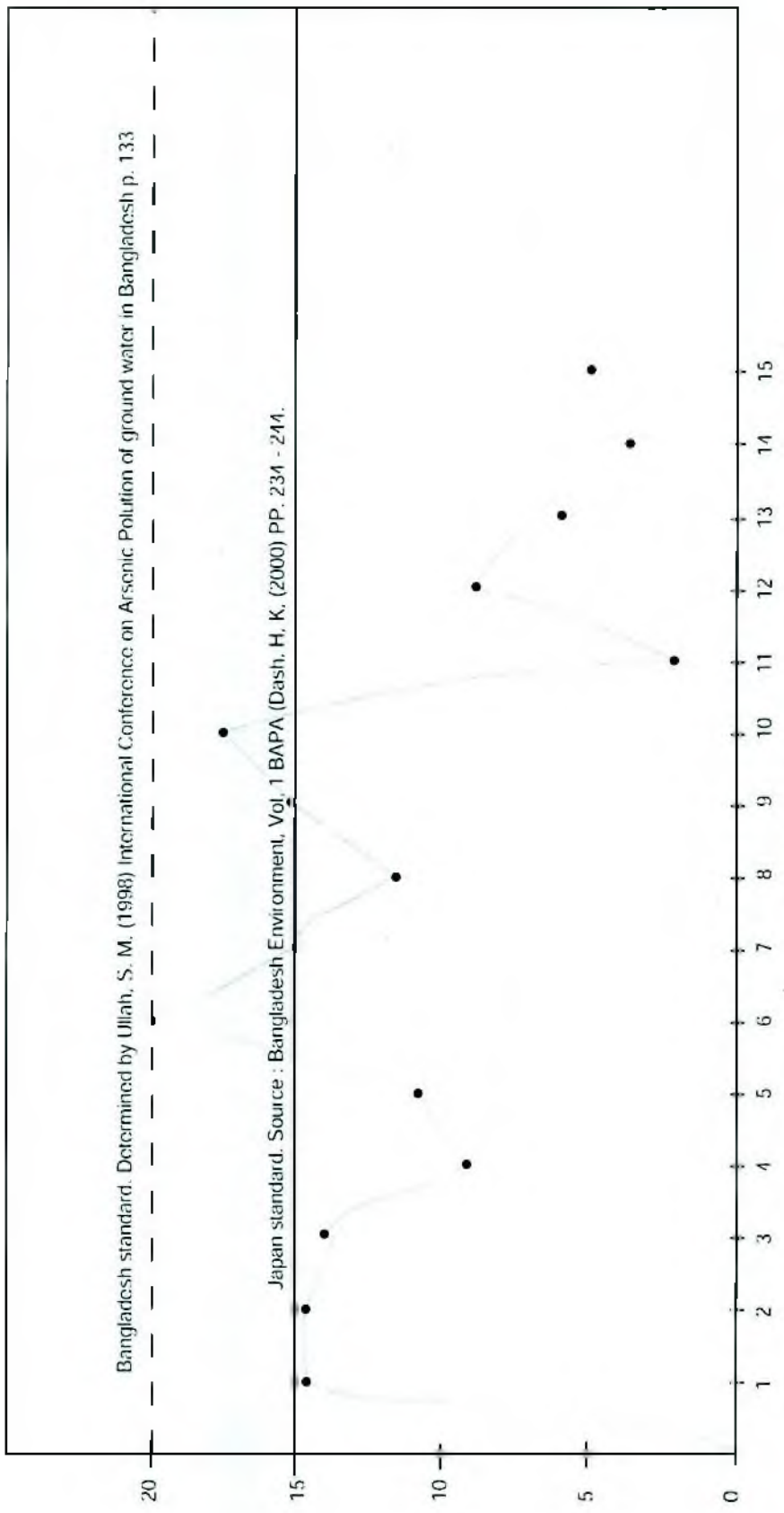


Figure-6.18: Arsenic in Soil

Arsenic is found in the earth's crust at an average level of 2 mg/kg. Most natural soils contain low level of arsenic, but industrial wastes and pesticide applications may increase concentration (WHO, 2001). Background concentrations in soil range from 1 to 40 mg/kg, with a mean value of 5 mg/kg (Bowen, 1979). Naturally elevated levels of arsenic in soils may be associated with geological substrata such as sulfide ores. Anthropogenically contaminated soils can have concentrations of arsenic up to several percent (NAS, 1977). Arsenic concentrations of up to 27,000 mg/kg were reported in soils contaminated with mine or smelter wastes. It was reported arsenic levels of 20-100-35 500 mg/kg in soil around the effluent dumping point of an arsenical pesticide manufacturing plant. Peat may contain considerable quantities of arsenic. Minkkinen and Yliruokanen (1978) found maximum arsenic concentrations in various Finnish peat bogs of between 16 and 340 mg/kg dry peat. However, Shotyk (1996) analysed peat cores from the Jura mountains (Switzerland) and found mean total arsenic concentrations of 3.6 mg/kg at a depth of <30 cm and 0.16 mg/kg at between 69 and 84 cm. Higher levels of arsenic were found in the mineral sediments underlying the peat bogs, with mean concentrations of 6.4 mg/kg at 170 cm and 15.9 mg/kg at 650 cm. Soil on agricultural land treated with arsenical pesticides may retain substantial amounts of arsenic. Mean total arsenic concentrations of 50-60 mg/kg have been recorded for agricultural soils treated with arsenical pesticides (Takamatsu et al., 1982; Sanok et al, 1995). Walth and Keeney (1975) reported that arsenic-treated soils contained up to 550 mg As/kg.

Arsenic occurs in soils at an average concentration of about 5 to 6 mg/l, but mean arsenic contents in soils as high as 20 ppm in Italy, 14 ppm in Mexico, 11.2 ppm in China and 11 ppm in Japan have been reported (Ahmed, 2003).

Another study, in Japan, the maximum allowable limit of arsenic in soil is set at 15 ppm as determined by 1 N HCL extraction method (Yamene, 1979). This value has been compared the study area, Ramganj, Lakshmipur. In Bangladesh, the allowable limit value is 20 mg/kg soil (Ullah, S.M., 1998).

Table No. 6.5 shows that all the samples of soils contain arsenic. Figure shows that all the soil samples contain arsenic within Bangladeshi standard value. The Bangladesh standard value of arsenic in soil is 20 mg/kg. It's also seen from the figure that the contents of arsenic exceed the Japanese standard in two samples. The Japaneses standard value is 15 mg/kg.

Within 15 samples one sample contented high arsenic but it did not exceed Bangladeshi standard. This sample depth was 30 meters. In 55 meters depth arsenic concentration was low. It was less than 5 mg/kg.

The results of other parameter has not been shown in the graph. Because no standard value was get of them.

Iron : Results of chemical analysis it appears that among the samples, the highest concentration of iron is 19.3 mg/g soil. It is found in 65 meter depth (sample no. 13). The lowest iron concentration is found in 60 meter depth (sample no. 12). It contains 1.0 mg/g iron. According to the depth, there is no sequence of iron concentration.

Calcium : Table 6.5 shows that the highest calcium is found in 25 meter depth, sample no. 5 contains 17.2 per cent calcium. Among the 15 samples, the lowest calcium is seen in 15 meter depth. It is the sample no. 3 and contains 1.2 per cent calcium. In 40 meter, 50 meter and 70 meter depth calcium concentration are same.

Chloride : It appears from the table result, the highest and lowest chloride is 867.18 mg/g and 140.62 mg/g in 10 meter and 55 meter depth respectively. Sample no. 4 and 11 shows the highest the lowest concentration of chloride.

Megnesium : It is observed from the table that the highest concentration of magnesium is 6.0 per cent and the lowest concentration is 0.48 per cent that found in 55 meter and 75 meter depth (sample No. 11 and 15).

Sulphate : The table shows that the sulphate concentration is in 65 meter depth is 0.95 ppm/g. It is the highest range of SO_4. Among the 15 samples the lowest concentration is 0.18 ppm/g in the sample no. 12 and it is in 60 meter depth.

Nitrate: Results shows that the lowest nitrate of soil is observed 0.4 mg/lg soil in 50 meter depth. The highest concentration of nitrate is 3.3 mg/lg soil that is found in 55 meter depth.

6.4. Discussion:

Under the research on Groundwater Arsenic Contamination in Bangladesh: Geo-environmental Analyses in Ramganj Thana (Upazila) in Lakshmipur District was taken as a critical area for the investigation to determine the sources of the Arsenic in the groundwater. There is limitations of proper equipment to determine the actual arsenic mineral or minerals which under what environmental conditions goes or go into solution and contaminate the groundwater. The area selected for investigation is one of the worst affected areas in Bangladesh . The gravity of the Arsenic contamination is such that the area attracted the attention of the World Community and the attending related scientists who visited area, when they participated in the

International Seminar on Arsenic in Bangladesh 1998. The learned participants of the International Conference on Arsenic Contamination of Groundwater, Causes, Effects and Remedies, held in Dhaka from February 08 to 12. 1998. In their Dhaka Declaration opened, "The Cause of Arsenic Contamination is Geological". Even before that of conference on the problem, the Government of the Peoples Republic of Bangladesh was well aware of the problem of Arsenic contamination of groundwater particularly of the water in the shallow aquifers. Geological Survey of Bangladesh has the experience of research since eighties, appropriate equipment and manpower, was entrusted along with other related organizations by the Government to carry on research work on the sources Arsenic in the groundwater. Geological Survey of Bangladesh has a Core Library in Bogra where all rocks from Precambrian to Holocene Age are available. Samples of rocks and sediments either exposed or encountered in geological drilling holes were analyzed for the determination of Arsenic contents. The scientists in Bangladesh have taken this problem very seriously and attempted to contribute in their related fields and experience.

All the matters which form the rocks exposed or unexposed, water and air are not beyond the domain of Geography. Causes of any problem is related to the earth materials processes and time. Domain of Geography depicts what is going on in the present and what had happened in the past and what may be in the future. Arsenic contamination of groundwater is a part of Paleogeography- and a study of the affected area had the Paleogeographic Environment under which the Aquifer and aquitard materials had been deposited along with other materials either toxic or not.

Generalized Discussion on Paleogeographic Conditions related to Arsenic Pollution of Groundwater: The three great river systems the Ganges, the Brahmaputra and the Megna rivers which comprise 230 notable rivers drain a catchment areas of 1.5 million square kilometres. Rocks from the ages from Precambrian to the Holocene are exposed in the catchment areas. These rocks contribute sediments into the rivers' flow. The sediment loads is about 2.4 billion tons annually. And the sediments are carried by the river water which deposits the same in the land area and the rest is being deposited in the Bengal Fan from the time immemorial. It is beyond the scope of discussion which units of rocks contribute how much quantity of arsenic in the sediment loads. Amongst the rocks from the ages of Precambrian to Pleistocene, the Rajmahal Trap Rocks contain highest content of arsenic (8 ppm). The Rajmahal Trap Rocks are of volcanic origin. It is generally known that Volcanoes contribute sediments as ash or dust which contain high content of arsenic in the form of Mispickel (Arsenopyrite- $FeAs_3S$) deposited by the action of both hydrothermal solutions and vapours. In the hydrological domain, sediments can be produced, transported and deposited within the catchment areas only. But the ashes and dust produced by volcanoes may be deposited beyond the regime of hydrological environment. There was great episode in the earth history in Cretaceous Period when there were worldwide volcanic activity .In that period the Rajmahal Trap Rocks, the Deccan Traps in India were deposited on the surface of earlier rocks, which is well exposed and contribute sediment in drainage systems. This rocks have been found in the subsurface in Nawabganj and Naogain Districts. During this world wide volcanic episode, volcanic ashes and dust had been deposited all over the world. In addition to that Arsenic, transport from continents to the oceans

arises from natural processes, such as weathering and volcanism, About 45,000 metric tons of arsenic is weathered per year, 73 per cent of which is dissolved form Volcanoes contribute about 17,150 tons of arsenic per year over the globe. It is known that there was large scale volcanic activity in Toba, in Sumatra of Indonesia in 75,0000 B.P. The Ash beds have been studied in many parts of India and in a few areas in Bangladesh. The German Sonnee Mission in the Bay of Bengal recorded 1 ppm 24 ppm arsenic in the marine sediments in the Bengal Fan. In the Bengal Fan they have found the ash bed well preserved. Samples of Toba Ash from the Bay of Bengal serves as model sample for the study of the remarkable Volcanic activity in an area very close to Bangladesh in the late Pleistocene Time. It is remarkable that during that time the sea level was 150 metres below the present sea level. Since that time there were many eustatic changes but during 6000 B.P (Noahas) time it was 2 metres above the present sea level, when the greatest floods occured in historical time.

Pleistocene Terraces mostly formed tablelands. During Toba volcanic activity, the landmass of Bangladesh was up to Latitude N 21^0 and beyond south. During that time there were deep river valleys in the present plain lands of Bangladesh. Drilling data in the Sangu River Valley shows that the base of alluvium is more than 52 metres. Since Toba Volcanic Activity there was gradual rise of sea level with minor rise and fall of the sea level bringing environmental changes i.e., the changes in the level of erosion and deposition of the materials of aquifer and aquitard . It is to note Toba Ash that fell on the surface of Bengal Fan was immediately preserved by sedimentation. But the environment in the present Bangladesh

Land Mass was different, where there were deep valleys and eroded surface. The Toba Ash that fallen was washed away and was deposited where there depositing environment. The seasonal variations also worked on the re-erosion and re-deposition of sediments. Toba Ash has a more or less contribution in the content of arsenic in sediments. During the test drilling which was aimed at to study the environment of sedimentation of materials of aquifer and aquitard along with the arsenic there it was observed the changes in lithology up to that thickness of sediment of about 50 metres.

Comparative Study: Since the time when the Government of the Peoples Republic of Bangladesh came to know the problem has taken it as national problem which geopardise the Government's Enthusiastic Program of supplying safe drinking water to the people in the rural areas in Bangladesh, where nearly 80 per cent of the people are living. Now in the rural areas in Bangladesh 97 per cent of the people are dependent on tubewell water which is being drawn from shallow aquifers ranging in depths from 20 m to 40 m.

In pursuance of the Government's endeavour to determine the sources of arsenic materials in the groundwater, the Geological Survey of Bangladesh in collaboration of Atomic Energy Commission of Bangladesh, Bangladesh Water development Board and Department of Public Health Engineering carried out chemical analyses of rocks and sediments either exposed or encountered during drillings. It is to note that all most all the rocks and sediments ranging in age from Precambrian to the Present contain arsenic. Rocks those occur in the catchment areas of the river systems of Bangladesh are found within the territory of Bangladesh. The main sources of sediments prevailing in Bangladesh are the catchment areas of the river systems.

The British Geological Survey (BGS) came forward to study the problem in collaboration with Geological Survey of Bangladesh and with other departments. However, the BGS in collaboration with related organizations particularly with DPHE carried out research work and submitted a report which may be considered as the base work in the evaluation of the Arsenic contamination of groundwater in Bangladesh. . The salient accomplishments of the report are: 1. Arsenic is of natural origin and the source is diseminatted. 2. Arsenic concentrations are greatest in finer grained sediments. 3. And the primary association is with Fe oxyhydroxides. The key process of arsenic mobilization desorption and/or dissolution of Fe oxides. 4. The concentration of As in aquifer sediments (0.4 - 10 mg/Kg. in their study) are consistent with normal abundances. But reducing conditions and low hydraulic gradient (long water residence times) led to the high dissolved As concentrations. In contrast to the results of BGS and DPHE, Chakrabarty who is conducting studies in West Bengal in India has proposed that oxidation of iron sulfide containing arsenic is the principal mechanism of arsenic release to the groundwater.

United States Geological Survey which has vast experience of research activity on such problem in collaboration with the Geological Survey of Bangladesh has carried out investigation in Ramrail village in Brahmanbaria District, Bangladesh. They have submitted a report. The Research workers tried to avoid many a assumptions and carried out basic work with appropriate equipment (X-ray Absorption Fine Structure Spectroscope Studies on Arsenic Species in Soil and Aquifer Sediments). So as cite the over all situations under which problem has been being created. They in their report have embodied their achievements and end the report with an

expectation to carry on more research work on the problem. The discussion conclusions they made are as flows:

The visual contrasts between Holocene and Pleistocene sediment is mainly due to the difference in abundance of Fe oxyhydroxide grain coatings, reduces sediment also tend to have higher proportions of clay and silt relative sand, but mineral compositions of both types of sediments are similar. The colour difference between two horizons reflects the depositional history of the region; the material that now composes the lower aquifer horizon was at least partially oxidized during last glacial period. Deposition of the initially oxidized gray black sediments filled in the dissected delta as sea level rose and continued to accumulate at present. XAFS analyses reveals that As (III) predominates in the upper Holocene aquifer sediment and As (IV) predominates in the lower Pleistocene sediments. Opposite trend is observed in the soil pit samples; As(V) predominate in surface sediments As(III) is detected 5m depth . The concentration of dissolved As is higher in the upper Holocene deposit than in the lower Pleistocene deposit suggesting correlation between as oxidation state in sediment and total dissolved As concentration. No significant change on As speculation occurs over the interval between 24 and 35 m, but the As concentration in this range rises dramatically to 0.760 mg/l. This zone of Arsenic concentration approximately coincides with a zone of changing redox condition.

The BGS / DPHE study documented the association between solid phase and Fe -hydroxide. Our study adds the additional information that as on this mode of association is mainly as (V). As(III) is found on other forms suggesting the clays, micas or Al oxyhydoxides.

6.5. Findings:

- The area lies in the coastal part of Bangladesh and also lies in the lower end of the combined influence of all the great river systems- the Ganges, the Brahmapura and the Meghna.
- During drilling under the project it is recorded a notable unconformity at depth of about 50 meters, which corresponds the approximate sea level during the Late Pleistocene.
- As because the area lies in the coastal part of the Bay of Bengal, it had marine influence which has influence on the pattern of sedimentation. Fine grained sediments are predominant, which generally contain more arsenic.Due to environmental condition, the thickness of aquifers is thin.
- Arsenic is released and mobilized by reductive dissolution of iron-oxydydroxide in reducing environment of the aquifer in the study area.
- The depth of the tubewell and polder plays a expressive role on arsenic. Both categories of tubewells (shallow and deep) are badly reach in arsenic.
- The study area contains variable concentration of arsenic from 0.005 mg/l up to 1.33 mg/l. This variation is not random over the area. The lowest concentrations of arsenic contents deep tubewell. The lowest concentration of arsenic in shallow tubewell in 0.03 mg/l.
- Arsenic concentration is high in the outside polder. The study area is a high arsenic intensity zone. High arsenic zone is found in the south (1.33mg/l) side of the study area. Comparatively low arsenic is found northwestern side and polder inside of this area.

- A distinct pattern of arsenic concentration is also found vertically.
- For low-lying flood plains, arsenic is highly deposited.
- It is found a clear variation between field kit test and laboratory method of arsenic. Seasonal variation was also the study area.
- Different chemical parameter's variation is also cause of high arsenic concentration.
- Soil samples contain very high arsenic level.
- Excessive use of underground water to increase rice production by "Green Revolution" Project.
- Arsenic Poisoning is one of the leading problem of the study area.

CHAPTER SEVEN

7. SOCIO-ECONOMIC, HEALTH SITUATION AND ENVIRONMENTAL VARIABLE OF THE STUDY AREA

7.1. Introduction :

Socio-Economic, Demographic health Situation and environmental variable and discussion of this aspect have been presented in this chapter.

Table-7 : Socio-demographic characteristics of the respondents, N=105

Table-7.1: Age

Age	Male		Female	
(Yearly)	No.	Per cent	No.	Per cent
10 – 20	9	15.8	8	16.7
21 – 30	24	42.1	20	41.7
31 – 40	17	29.8	10	20.8
41 – 50	5	8.7	5	12.5
51 – 60	2	3.5	4	8.3
Total	57		48	

Table-7.2: Education

Level of Education	No.	Per cent
Degree & above	7	6.7
H.S.C.	12	11.4
Secondary	22	21.0
Primary	42	40.0
Illiterate	22	21.0
Total	105	100

Table-7.3: Occupation

		Male		Female	
		No.	Per cent	No.	Per cent
Farmer		10	17.5	0	0
Business		11	19.3	0	0
Employer	Govt	3	5.3	2	4.1
	Private	7	12.3	0	0
Housewife		0	0	39	81.3
Day Labourer		16	28	0	0
Students		3	5.3	5	9
Others		7	12.3	2	4.2
Total		57		48	

Table-7.4: Monthly Expenditure (Taka) :

Taka	No.	No.	Per cent	Per cent
> - 1000	11	5	10.5	4.8
1001 – 2000	30	36	28.6	34.3
2001 – 3000	36	15	34.3	14.3
3001 – 4000	20	32	19.6	30.5
4001 & Above	3	17	7.6	16.2
Total	105	105	100	100

Table-7.5: Monthly Income (Taka)

Taka	No.	Per cent
> - 1000	5	4.8
1001 – 2000	36	34.3
2001 – 3000	15	14.3
3001 – 4000	32	30.5
4001 & Above	17	16.2
Total	105	100

Table-7.6: Dwelling Time (Family) :

Years	No.	Per cent
7 – 5	5	4.8
6 – 20	10	9.2
21 – 35	12	11.3
36 and since Birth	28	74.3
Total	105	100

Table-7.7: Family Member :

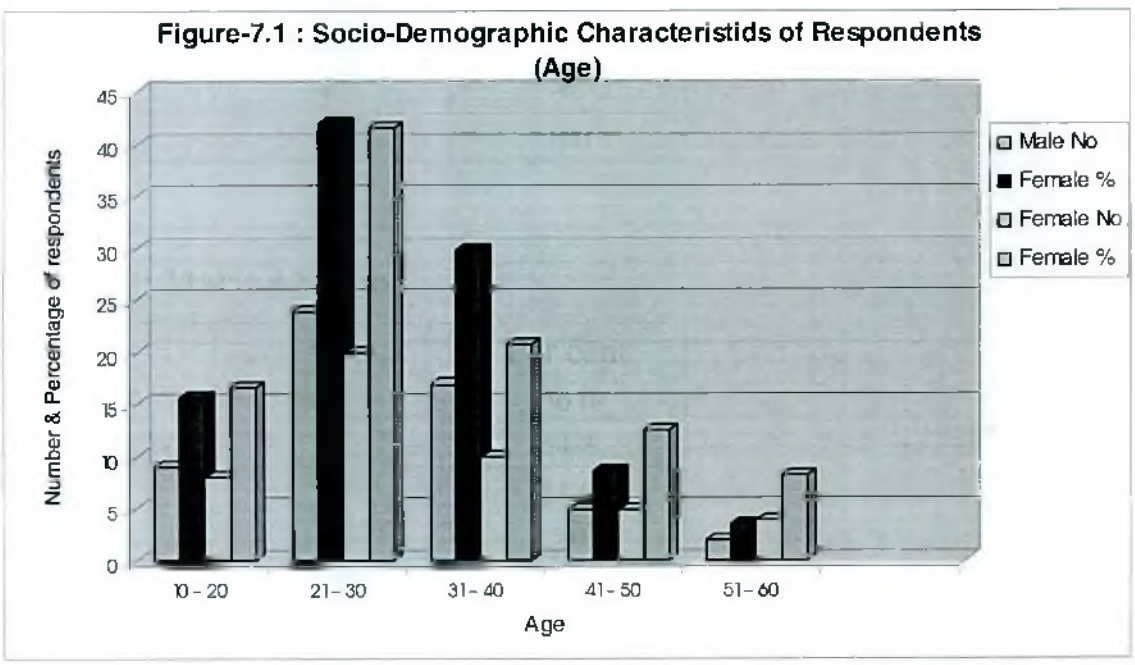
Family Size	No.	Per cent
1 – 5	19	18.1
6 – 10	77	73.3
Above 10	9	2.6
Total	105	100

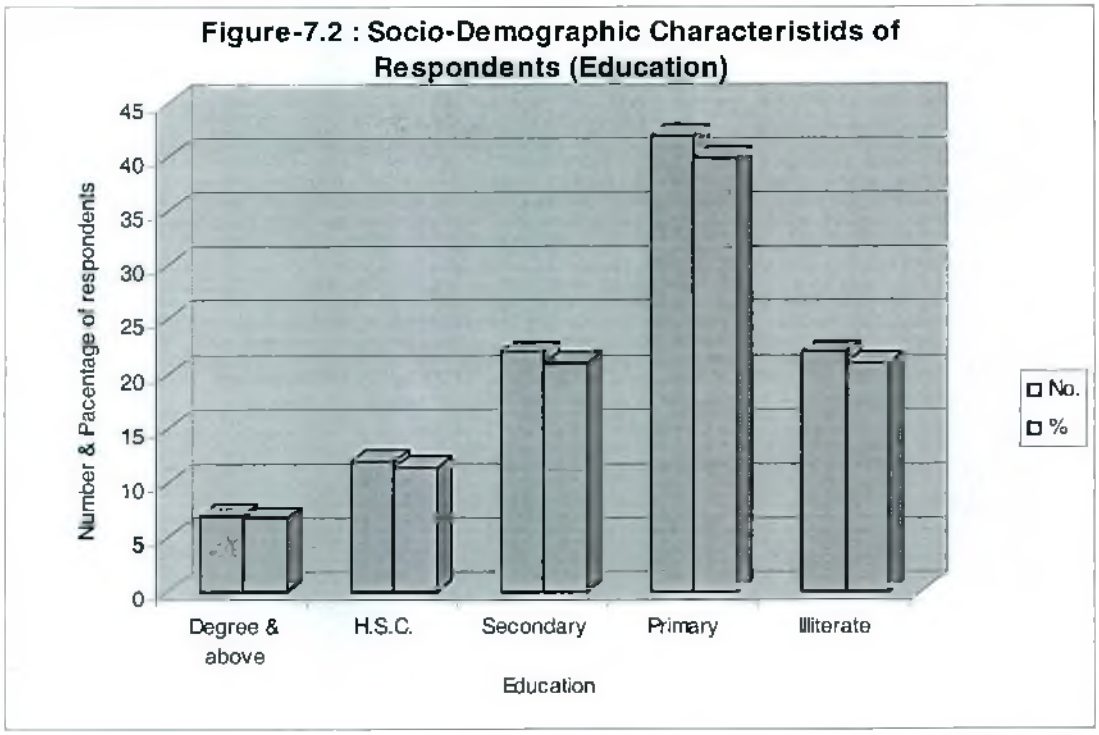
Table-7.8: Social Status

Level	No.	Per cent
High	18	17.1
Medium	45	42.9
Low	42	40
Total	105	100

Table-7.9: Marital Status

Variable	No.	Per cent
Married	59	56.0
Unmarried	36	34.3
Widow	7	11.9
Widower	3	5.0
Total	105	100





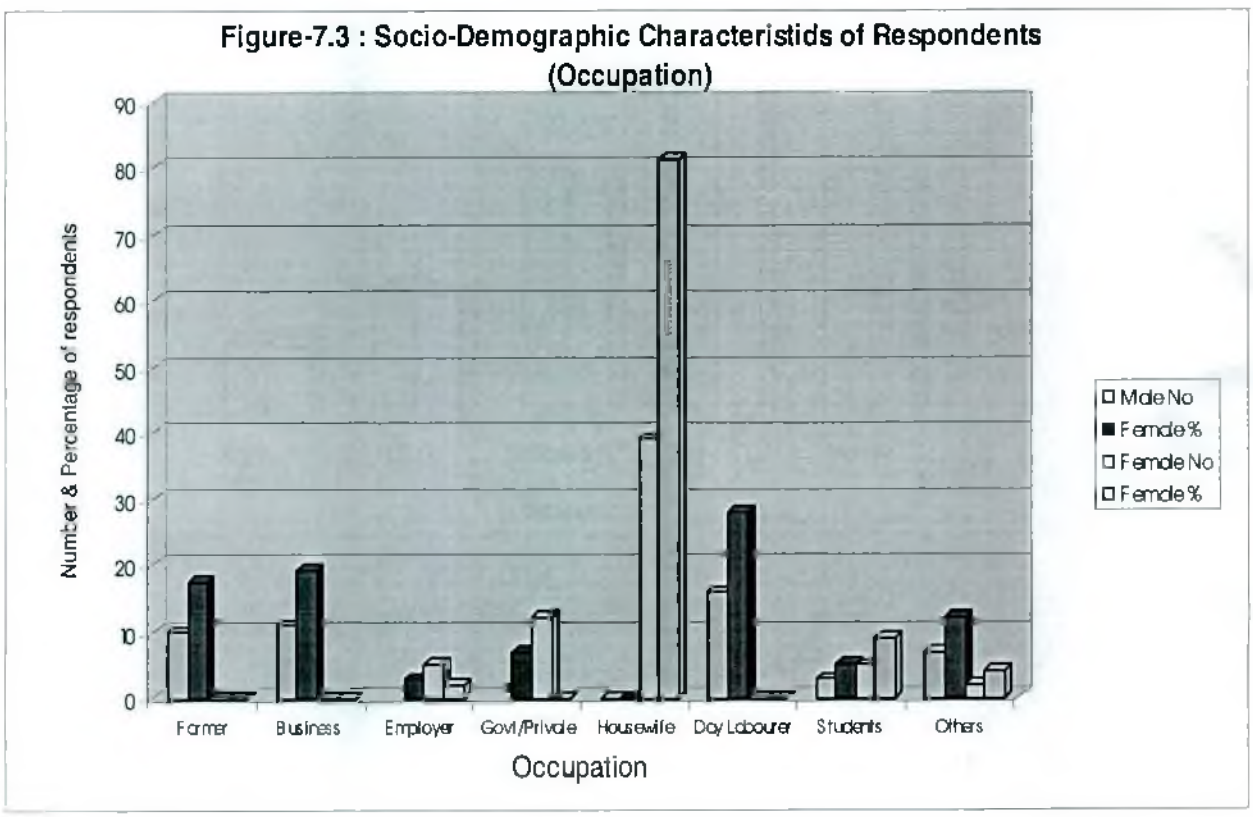


Figure -7.4: Socio-Demographic Characteristids of Respondents (Dwelling Time)

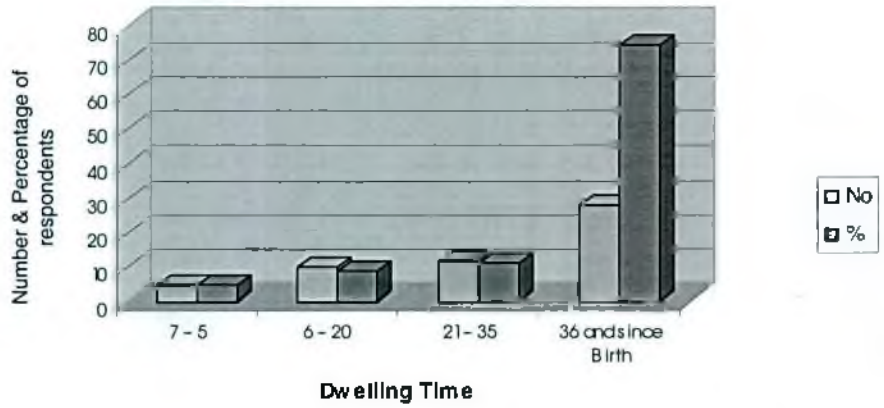


Figure-7.5 : Monthly Expenditure and Income (Taka)

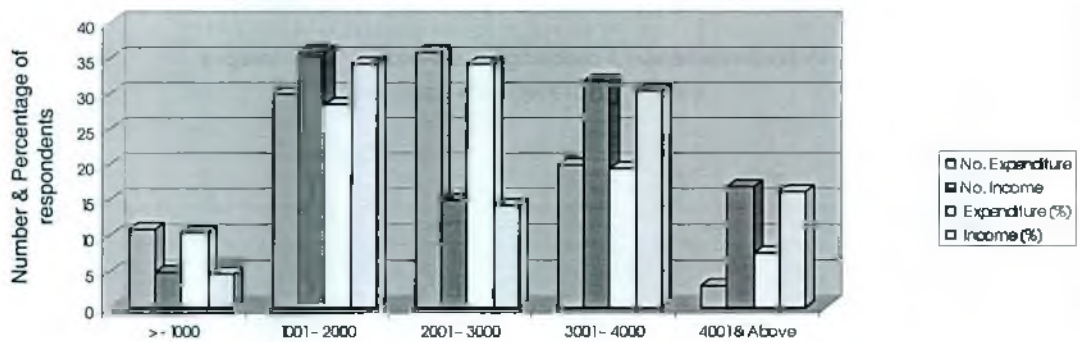
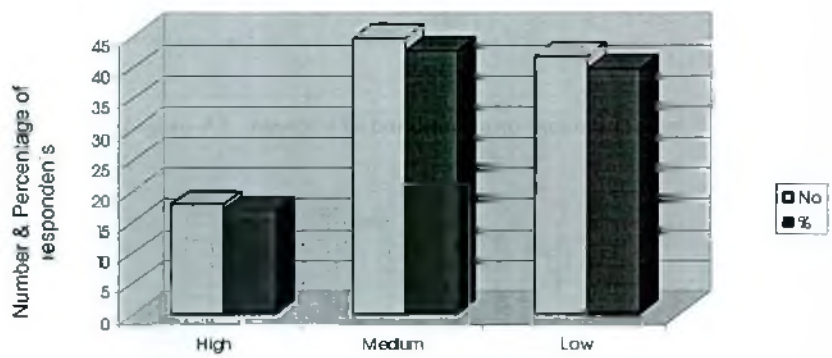


Figure-7.6 Social Status



7.2. Socio-Economic and Demographic situation and Arsenicosis Diseases Problem in the Study Area :

One hundred five (57 male and 48 female) arsenicosis patients were identified from this study area. Their age ranged from 10 years to 60 years.

Socio-demographic characteristics of the respondents are shown in table-7. It is seen that out of 105 cases 57 (54.3 per cent) were males and 48 (45.7 per cent) were females. Of the total respondents of males 15.8 per cent were within 10-20 years of age group and 16.7 per cent females were same age group, 43.1 per cent male and 41.7 per cent female were in 21-30 years age group. 29.8 per cent arsenicosis male patients and 20.8 per cent female arsenicosis patients were in 31-40 years of age group. About 9 per cent (8.7 per cent) male and 12.5 per cent female were in age group of 41-50 years.

51-60 years age group. The age limit of maximum number of patients was within 21-30 years (Table-7.1).

Among the respondents 21 per cent were illiterate, 40 per cent got primary education, 21 per cent got secondary education and 11.4 per cent got H.S.C education. The level of education of the respondents of degree and above was only 6.7 per cent (Table-7.2).

Regarding occupation (Table-7.3) it was seen that 17.5 per cent respondents were farmer, 19.3 per cent respondent were businessman, 28 per cent respondents were day labourer, out of 57 male respondents. More than 81 per cent respondents were housewives out of 48 female respondents. About 2 percent respondents were employer (govt. 4.8 per cent and 7 per cent private), 7.6 percent respondents were students and 8.6 percent respondents were others occupied (agri-labourer, self employed, rickshaw puller etc.).

Dhar et al in a study in Lakshmipur, Bangladesh apprehended that better economic conditions leading to maintain better nutritional status of population may have a role to prevent arsenicosis, at least partly. Monthly income of the respondents in this area is comparatively better than other arsenic affected area. It was observed in Table 7.6 that 4.8 per cent respondents earn hardly 1000 Tk. per month, 34.3 per cent respondents earn 1001-2000 Tk per month. It was the highly percent of respondents. 14.3 per cent respondents earn 2001-3000 Tk. per month, 32 (30.5 per cent) respondents earn 3001-4000 Tk. per month and only 16.2 per cent of the total respondents earn above 4000 Tk. per month. The most of the females and some males do not earn single money.

Most of the respondents said that their income and expenditure is equal. 34.3

per cent respondents expense 2001-3000 Tk. per month and it was the high responder of the expenditure characteristics. Only 7.6 per cent respondents expense above 4000 Tk. per month.

Here females, children and students' expense and income was considered as their custodian and custody income.

In terms of length of dwelling, the percentage of since birth respondents was near 74 (74.3 per cent), 11.3 percent lived for 21-35 years, 9.2 percent lived for 5-20 years and 4.8 percent respondents lived for 5 years or less respectively (Table-7.6).

Most of the families were large sized. About 73 percent respondents were having more than 6 members in their family (Table-7.7), some family's member was more than 10, the percentage of this respondents was 8.6, 18.1 per cent respondents were live in 1-5 family size.

More than 1 arsenicosis patients were living in every houses of this study area. 1-4 arsenicosis patients were in 66.7 percent and above 4 arsenicosis patients were in 33.3 percent respondenters family.

Table-7.8 also shows that 17.1 per cent respondents were high status, about 43 per cent medium status and 40 per cent low status respectively. Out of 105 cases 98 (93.3 per cent) respondents were Muslim and 7 (6.7 per cent) respondents were Hindu.

Regarding the marital status it has been observed that 56 per cent respondents were married and 34.3 per cent respondents were unmarried. Out of 59 married cases about 12 per cent (11.9 per cent) and 5 per cent respondents were widow and widower respectively (Table-7.9).

Table-8.1: Social Information

Types of problem	Yes.		No.		Not applicable	
	No	%	No	Per cent	No	Per cent
Marriage	10	9.5	70	66.7	25	23.8
Divorce	5	8.5	60	87.1	40	38.09
Separation	0	0	66	62.9	39	37.1
Maladjustment (cooking, eating etc)	0	0	94	89.52	11	10.5
Physical Assault	0	0	46	43.8	59	56.2
Being forced to go back to parents house	2	3.4	26	24.8	77	73.3
Being ignored in school	0	0	15	14.3	90	85.7
Unfair treatment in school	0	0	15	14.3	90	85.7
Differential treatment in service	0	0	16	15.2	89	84.8
Non-acceptance by Neighbour	22	19.5	50	47.6	33	31.4
▫ Socially Boycott	0	0	0	0	0	0
▫ Economically Refuse	19	86.4	0	0	0	0
▫ Agricultural Refuse	3	2.9	0	0	0	0
Facing Fatua by Religious Leaders	0	0	99	94.2	6	5.7
Bad Behaviour by Doctor	0	0	87	82.9	18	17.4
Disastrous help by Neighbour	90	85.7	0	0	15	14.3
Boycott from social function	0	0	65	61.9	40	28.1

7.3. Social Information of the Respondents:

Different types of social problem are arising from arsenic poisoning e.g. community refusal, discrimination, unhappy condition in conjugal life, problems in child development etc. Table-8.1 reveals that many specific problems have been observed among the arsenicosis patients. Respondents were questioned about marriage problem on whether yes or not. Among the respondents 9.5 per cent told that marriage was a problem and 66.7 per cent replied in the negative. It was not applicable for 23.8 per cent respondents. But who were yet then unmarried they faced great problem getting married. Out of 59 married cases, 8.5 percent respondents told spouse (1 male and 4 females) divorced them. No incidences of separation, maladjustment and physical assault were found in case of either males or females. Where, not applicable 3.09 per cent; separation 37.1 per cent, maladjustment 10.5 per cent and physical assault 56.2 per cent respectively.

Out of 59 marriage cases, 3.4 percent respondents were being forced to go to parents house. No incidences of being ignored in school, unfair treatment in school, differential treatment in service, facing "Fatua" by religious leaders, bad behaviour by doctor and boycott from social function were observed in the study area. Non-acceptance by neighbour was 19.05 per cent (Economically refuse 86.4 percent, agricultural refuse 2.9 per cent). About 86 per cent (85.7 per cent) respondents told that they got any disastrous help by the neighbour, it was not applicable for 14.3 per cent respondents.

Table-9.1: Physical Incidental Informations Manifestation of Arsenicosis

Years	No.	Per cent
> - 1	10	9.5
1 – 2	11	10.5
3 – 5	50	57.1
5 and above	24	22.9
Total	105	100

Table-9.2:Treatment for Arsenicosis Patients:

Rural Treatment	No.	Per cent
Yes	77	73.3
No	23	21.9
Not applicable	5	4.8
Spinach	21	27.3
Exorcising and Incantation	26	33.8
Amulet and Talisman	30	39.0
Total	105	100

Source : Field Survey, 2002

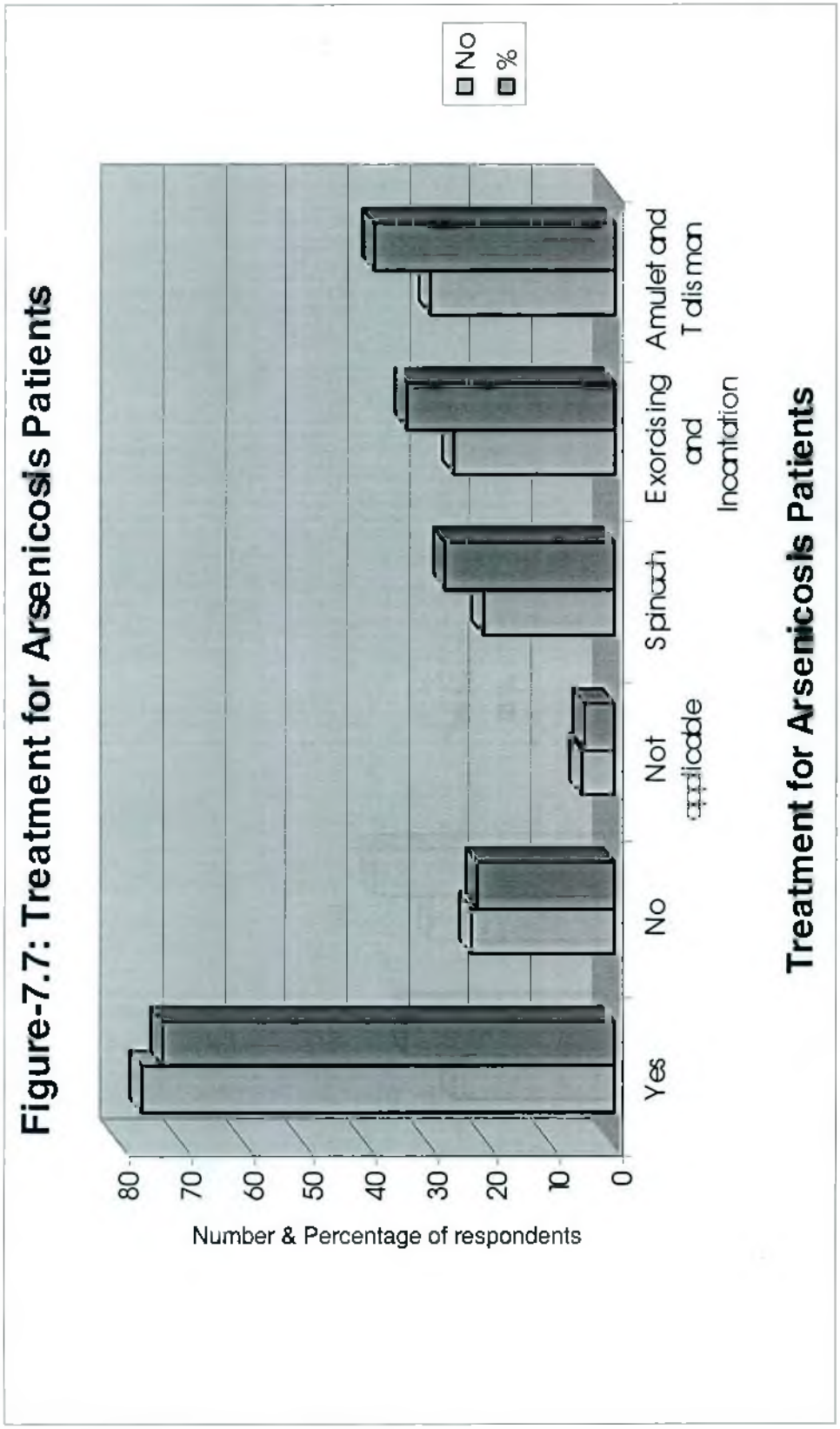


Figure-7.7: Treatment for Arsenicosis Patients

7.4. Physical Incidental Information:

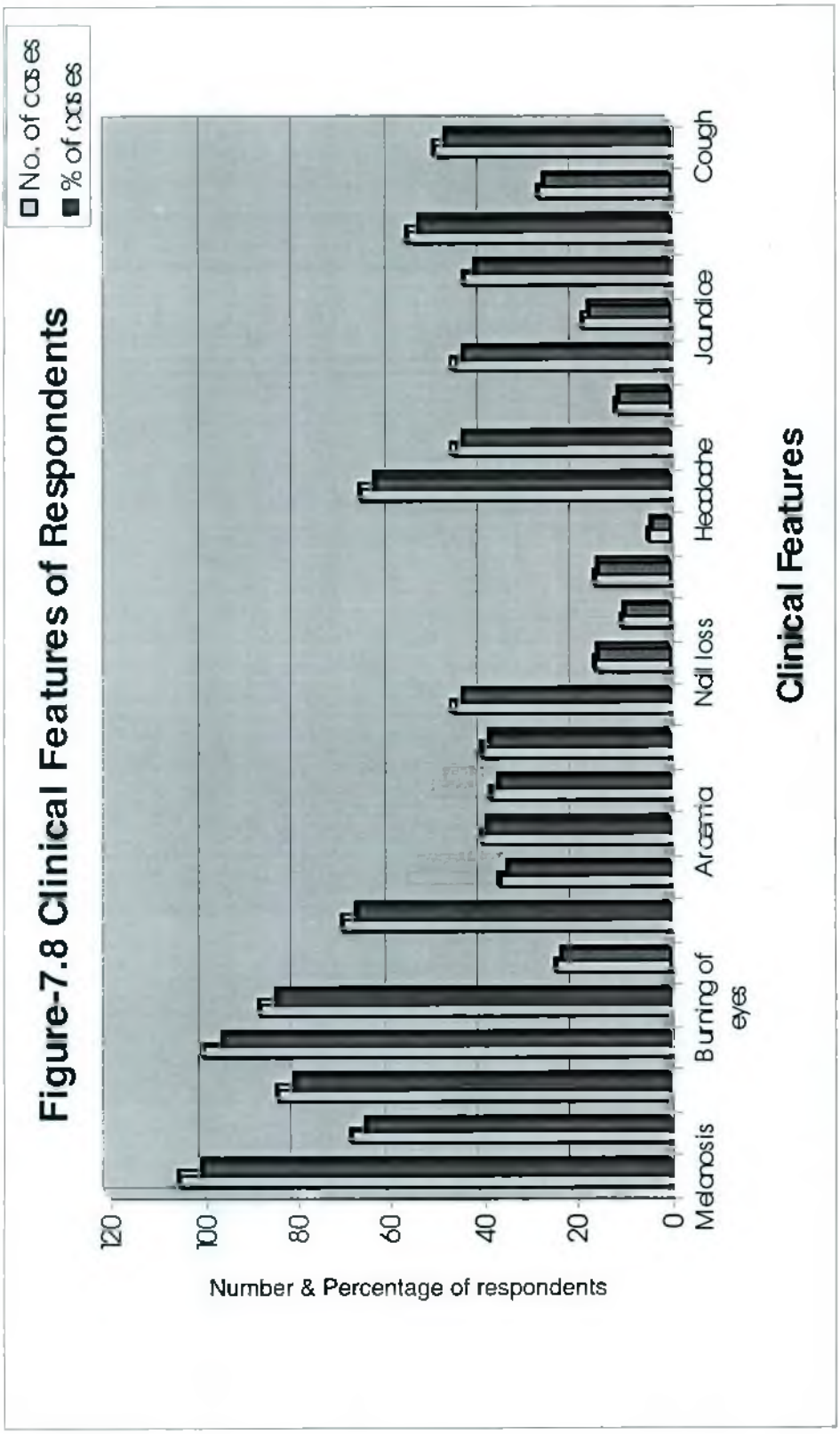
The symptoms of arsenic toxicity may take 8-10 years to be manifested in a persons body after the patient starts drinking arsenic contaminated water. This period differs from patient to patient, depending on the quantity/volume of arsenic ingested, nutritional status of the person irrespective of gender, immunity level of the individual and the total time period of arsenic ingestion (DCH 1997 and Bhuiyan, 2001). About 10 per cent (9.5 per cent) respondents told that they were suffering in arsenicosis from < 1 year (Table-9.1). More than 10 per cent (10.5 per cent) from 1-2 years, 57.1 per cent from 3-5 years and 22.9 per cent above 5 years, respondents were suffering in arsenicosis respectively. Most of the respondents (57.1 per cent) realized that the symptoms of arsenic manifested from 3-5 years ago.

Respondents were asked about the rural treatment of arsenicosis. 73.3 per cents patients told that they had taken rural treatment and about 22 per cent (21.9 per cent) replied in the negative and 4.8 per cent respondents told that they had not need this rural treatment or they didn't believe the rural treatment. Out of 105 cases, 77 respondents (23.3 per cent) were taken rural treatment. Among 77 cases, 21 patients (27.3 per cent) took spinach treatment, 33.8 per cent took exorcising and incantation treatment and 39 per cent took amuletic and talismanic treatment (Table-9.2).

Table-10.1: Clinical features of the Respondents

Symptoms & Signs	No. of cases	Per cent of cases
Melanosis	105	100
Karatosis	68	64.8
Lecu Melanosis	84	80.0
Weakness	100	95.2
Burning of eyes	88	83.8
Diarrhoea	24	22.9
Parenthesia	70	66.7
Pagmantation	36	34.3
Araemia	40	38.4
Capillary/flush	38	36.2
Contact Dermalitis	40	38.1
Hair delayed loss	46	43.8
Nail loss	16	15.2
Convulsion	10	9.5
Tremor	16	15.3
Coma	4	3.8
Headache	66	62.8
Dysphasia	46	43.8
Vomiting	11	10.5
Weight Loss	46	43.8
Jaundice	18	17.1
Oliguria	44	41.3
Pericarditis	56	53.3
Cangrene	28	26.7
Cough	50	47.6

Source : Field Survey, 2002



7.5. Clinical Features of the Respondents:

There is significant relationship between the arsenic in water and human health. Table-10.1 reveals that among one hundred and five cases melanosis was pre cent in all the respondents. Majority of the respondents had weakness (95.2 per cent) and burning of eyes (83.8 per cent). Among the respondents, 80 per cent expressed that arsenic causes lecumelanosis and 64.8 per cent told that karatosis is caused by arsenic in body. This table also reveals that Diarrhoea was presented in 22.9 per cent patient. More than 66 per cent patients were suffering in Paresthesia. Pigmentation was the caused by arsenic, it was expressed by 34.3 per cent patients. Anaemia is also cause of arsenic and 38.1 per cent respondents expressed it. About 36 per cent (36.2 per cent) respondents told that capillary flush is the cause of arsenic. Contact Dermatitis was an agonising for 38.1 per cent respondents. This table also reveals that hair delayed loss was presented in 43.8 per cent respondents. More than 15 per cent respondents expressed that nail loss was cause of arsenic. Among the respondents 9.5 per cent told that convulsion is caused by arsenic. Tremor was presented in 15.2 per cent respondents. About 4 per cent (3.8 per cent) told that arsenic causes coma. Headache is one of the leading clinical problems of the respondents. Against this question 62.8 per cent respondents replied in the positive. About 44 per cent (43.8 per cent) respondents expressed for dysphasia. Table-10.1 is also reveals vomiting, weight loss and jaundice were presented in 10.5 per cent, 43.8 per cent and 17.1 per cent respectively. About 42 per cent (41.9 per cent) respondents expressed that oliguria was a major problem for them. More than 53 per cent respondents told that pericarditis was a serious clinical problem for the arsenicosis patients. Among the respondents, 26.7

per cent expressed that gangrene was the caused by arsenic and it was the worst presented in hands and foots in the respondents. Cough with or without expectoration were presented in 47.7 per cent respondents.

So, acute toxicity involves many organ systems in human body e.g. respiratory system, hepatic, renal cardiovascular hematopoitic, dermatlogic, neurologic gastrointestinal and ophthalmic. The basic lesions are edothelial cellular toxicity capillary damage and axonal damages. Symptoms and number are shown in table-13, according to, Gorby 1994. There is no known dose response relationship to development of symptoms for chronic arsenicosis has. Researchers think in a definite relationship in development of symptoms and dose of arsenic. So for a low dose limit is given by WHO as a guideline for drinking water (0.01 mg/l). After the appearance of inorganic arsenic in groundwater and its wide range. The respondents told that arsenicosis is a threat to public health.

Table- 11: Psychological Information

Table-11.1: Loneliness

Variable	No.	Per cent
Yes	63	60.0
No	22	21.0
No Response	20	19.5
Total	105	100

Table-11.2: Distressed/Depression

Variable	No.	Per cent
Always	42	40
Sometimes	47	44.8
No distress	16	15.2
Total	105	100

Table-11. 3: Being out of hearts by whom

Variable	No.	Per cent
Spouse	22	21
Sons & daughters	0	0.0
Neighbour	40	30
No Response	43	41
Total	105	100

Table-11.4: Being Out of sight of all

Variable	No.	Per cent
Yes	6	5.7
No	26	24.8
No Response	73	69.5
Total	105	100

Table-11.5: Privacy of this problem

Variable	No.	Per cent
Everybody know early	83	79.0
You have known everybody	22	21
Others	0	0.0
Total	105	100

Table-11.6: Behaviour of Others

Variable	No.	Per cent
Satisfactory	56	53.3
Acceptable	34	32.4
Unsatisfactory	3	28.6
No Response	12	11.4
Total	105	100

Table-11.7: Spontaneous Mood

Variable	No.	Per cent
Very good	3	2.9
Good	18	17.1
Bad	73	70.0
Very bad	11	10.5
Total	105	100

Table-11.8: Curse of Nature/God/Allah

Variable	No.	Per cent
Yes	52	49.5
No	30	28.6
No Response	23	22.0
Total	105	100

Table-11.9: Arsenicosis is a Contagious Disease

Variable	No.	Per cent
Yes	80	76.2
No	15	14.3
No Response	10	9.5
Total	105	100

7.6. Psychological Information:

Psychological or mental problem is one of the terrifying situations of the study area. Arsenic problem generated problem in our public health situation as well as social and personal life. Respondents were asked about loneliness in his/her life. The percentage of loneliness patients was 60 in case of both sex. Twenty one per cent replied in the negative and 19.5 per cent respondents avoid this question (Table-11.1). Fourty per cent respondents reported that the arsenic patients had been suffering from a mental agony because of their problem in always. About 45 per cent (44.8 per cent) respondents sometime fell mental anxiety and depression. Only 15.2 per cent patients answered that they did not fell distress or depression.

According to the respondents, married couples who are suffering from arsenic poisoning might face unhappy conjugal or family life. 21 per cent respondents mentioned about such problem by their spouse. 38 per cent respondents told that they were being out of hearts by neighbour. 41 per cent patients avoided this question. But no respondents were being out of hearts by their sons and daughters.

Table-11.4 shows that 5.7 per cent respondents were being out of sight of all. Those arsenic affected patients fell shy or hesitate to participate in their neighbours' social events, 24.8 per cent respondents replied that they were not being out of sight of all and about 70 per cent (69.5 per cent) respondents were silent to say anything.

Regarding privacy of the arsenicosis, 79 per cent patients said that everybody had known their problem easily and 24 per cent respondent had known everybody from himself or herself.

About 53 per cent (5.3 per cent) respondents were satisfied and 28.6 per cent respondents were unsatisfied for behavior of others. More than 32 per cent (32.4 per cent) respondents response that the behavior of others was acceptable. About 11 per cent (11.4 per cent) replied no response (Table-11.6).

Rejection by the fellows, friends or relatives to sit or to share make the affected person think that they are hated and unacceptable in their own society. This situation undoubtedly creates unbearable mental agony for the affected patients. For this reason majority per cent (70 per cent) respondents reported that their spontaneous mood was bad and ten and half percent said very bad. Only 2.9 per cent respondents told that their spontaneous mood was good and 17.1 per cent said very good (Table-11.7).

Many people have misconception regarding the symptoms of arsenic poisoning. They consider these symptoms as the symptoms of leprosy. A large number of respondents (bout 50 per cent) considered arsenic poisoning as "Gazab of Allah" or "God made curse" or "curse of nature" or "cause of evil spirits" or the "resultant of sin" and lack of education was mentioned as the main reason for such thinking by the people. 28.6 per cent respondents replied that arsenicosis was not "curse of nature" and 22 per cent respondents didn't response against above theme of arsenicosis (Table-11.8).

Finding show that 76.2 per cent respondents considered that arsenic problem was contagious or infectious or infectious disease. According to the respondents, it is contagious or infectious because this type of spots or problem is appeared at first in someone's body in a family or a community and then it starts to appear in other family members' body or in the body of neighbouring area people. 14.3 per cent respondents replied that arsenicosis was not contagious and 9.5 per cent respondents replied no response (Table-11.9).

Table-12: Geo-environmental Information:

Table-12.1: Water Use

Variable	No.	Per cent
Tubewells	105	100
Shallow	80	76.2
Deep	25	23.8
Total	105	100

Table-12.2: Cause of Arsenicosis:

Variable	No.	Per cent
Drinking of Deep Tubewells Water	2	9
Drinking of Shallow Tubewells water	103	97.1
Others	0	0.0
Total	105	100

Table-12.3: Reason why do not stop shallow Tubewells water

Variable	No.	Per cent
No alternative way	30	35.3
Lack of knowledge	33	38.8
Distance of the safe tubewell water	22	25.9
Total	105	100

7.7. Geo-environmental Information:

Table-12.1 shows that most of the respondents collect drinking water from shallow tubewells. It was about 76 per cent (72.2 per cent) and about 24 per cent (23.8 per cent) respondents collect drinking water from deep tubewells. It is clear that hundred per cent respondents collect drinking water from tubewells. Ponds, canals, rivers and other media were cut out for the awareness of respondents. Hundred per cent respondents told that they did not drink boiling water. About hundred (98.1 per cent) per cent respondents thought that the cause of arsenicosis was drinking of shallow tubewells' water and only about 2 per cent (1.9 per cent) respondents said that the cause of arsenicosis was drinking of deep tubewells water.

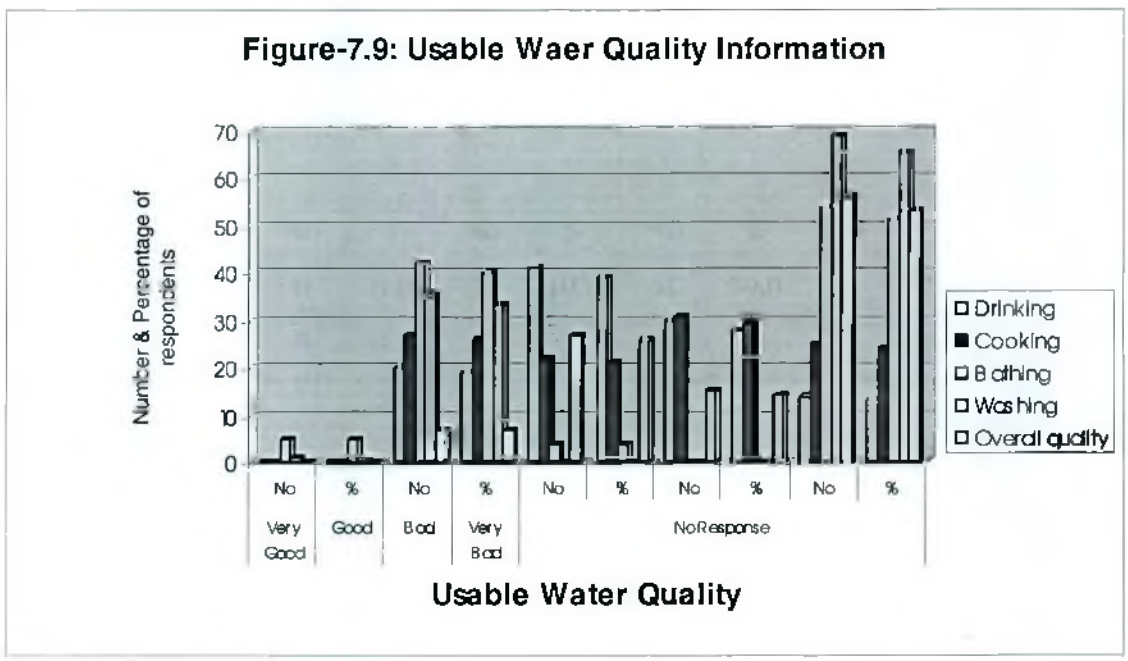
Regarding stop shallow tubewells' water it was observed that only 19 per cent patients stopped drinking of shallow tubewells water. Out of 105 cases 85 percent respondents (81 per cent) did not stop shallow tubewell's water.

Respondents were asked reasons why do not stop shallow tubewell water. Out of 85 cases, 35.3 per cent expressed that they had no alternative way of arsenic free water, 38.8 per cent respondents had lack of knowledge about arsenicosis and arsenic contaminated water. Distance of the safe water from home was also a reckonable (25.9 per cent) case. No respondents were mentioned filtration of water as an alternative safe water source for drinking purpose.

Table-13.1: Usable Water Quality Information

Variable	Very Good		Good		Bad		Very Bad		No Response	
	No	%	No	%	No	%	No	%	No	%
Drinking	0	0.0	20	19.0	41	39.0	30	28.0	14	13.3
Cooking	0	0.0	27	25.7	22	21	31	29.5	25	23.8
Bathing	5	4.8	42	40	4	3.8	0	0.0	54	51.4
Washing	1	0.95	35	33.3	0	0.0	0	0.0	69	65.7
Overall quality	0	0.0	7	6.7	27	25.7	15	14.3	56	53.3

Source : Field Survey, 2002



7.8. Usable Water Quality Information:

Groundwater is an economic resource apart from drinking, cooking, bathing, washing purpose; it is used in agriculture, industries and municipalities, water obtained from underground sources should be chemically pure and reasonably free from micro-organisms. Considerations in selecting a particular source for water supply depend on quality of water. Broadly speaking, the desired quality of a groundwater supply depends on the purpose of its use, i.e., in drinking, industry or irrigation (Todd, 1954).

Respondents were asked about the quality of water according to various variable of the study area. It was found that nobody could affirm water was very good for drinking purpose. Nineteen per cent said good 39 per cent said bad. More than 28 per cent (28.6 per sent) said very bad and 13.3 per cent was salient for their remarks respectively.

In cooking, among the respondents nobody said that contaminated water was very good but 25.7 per cent told that it was good for cooking. Bad and very bad was 21 per cent and 29.9 per cent respectively. About 24 per cent (23.8 per cent) avoided the question. For bathing purpose 4.8 per cent told very good 40 per cent told good. Only 3.8 per cent respondents told bad, nobody told very bad, 51.4 per cent respondent did not response.

In washing, out of 105 cases, 1 patient (0.95 per cent) told it was very good, 33.3 per cent told good, no one said bad and very bad, 65.7 per cent respondents did not express their opinion. Respondents were question about over all quality of water, it was observed that nobody said water was very good, only 7 patients (6.7 per cent) out of 105 cases, said water was good, 25.7 per cent told water quality was bad, about 14 per cent (14.3 per cent) told very bad and 53.3 per cent respondents were silent (Table-13.1).

Table-14: Water Pollution:

Table-14.1: Water Quality (Odour)

Variable	No.	Per cent
High Intense	0	0.0
Usual	0	0.0
Not known	105	100

Table-14.2: Water Quality (Taste)

Variable	No.	Per cent
Natural	66	62.9
Unnatural	0	0.0
Not known	39	37.1

Table-14.3: Water Quality (Colour)

Variable	No.	Per cent
Clear	72	68.6
Turbid	9	8.6
Do not know	24	22.9
Total	105	100

Source : Field Survey, 2002

7.9. Water Pollution:

Among the respondents, 100 per cent told there was no odour interm of water quality. 62.9 per cent respondents told that the quality of water in percent of taste was natural. Unnatural. told nobody and 37.1 per cent told that they did not know the taste of water was natural or unnatural.

Regarding the water quality of colour, 68.6 per cent respondents told the water was clear, 8.6 per cent told turbid and about 23 per cent (22.9 per cent) said that they did not know what was colour of their tubewells' water (Table-14).

7.10. Discussion

The consequence of arsenic contamination of groundwater is now considered as a great threat to the future generation of the country. The study was carried out among the people dwelling in a rural community of Ramganj Upazila of Lakshmipur district to find out the relation of arsenic with other parametres in water and soil both cases and the social and psychological scenario of arsenicosis patients in using arsenic contaminated water.

Samples survey result suggests that all the tubewells (except two deep tubewells) in the study area is contaminated with arsenic above the Bangladesh drinking quality standard of 0.05 μg/l. Most of the people in all statues and classes are contaminated in arsenicosis. The income rate is comparatively higher than other arsenic polluted area of Bangladesh. From this study it observes that marriage problem, divorce case, forced to go back to parents house (in applicable field), non-acceptance of neighbour have

been found in comparatively less. There are some secret-scandal mongering which heard that the patients of arsenicosis are to force0 many problems: the neighbours avoids the adults, children are refused to play with others, and the adolescent girls are often not married due to social discrimination but they are not faced to the field worker. The patients are suffering in arsenicosis for a long time and they have taken rural treatment. Spinach, exorcising and incantation, and amuletic and talismanic treatments are mentionable.

Melanosis is most common within the arsenicosis diseases. More or less 95 per cent patients are suffering from melanosis or leuco-melanosis or weakness, burning of eyes, paresthesia, pigmentation, araemia, capillary flush, nail loss, hair-delayed loss, contact dermatitis, karatosis, weight loss, oliguria, pericorditis, cough, gangrene etc are also common problem/disease within arsenicosis patients. Most of respondents to think that arsenic related disease in hereditary or contagious or curse from Allah.

Psychological problem such as: loneliness, depression, being out of hearts, being out of sight from all and bad behaviour are most alarming situations of the study area.

Most of the people depend on groundwater or shallow tubewell for collection of drinking water. Shallow tubewells water is main cause of arsenicosis. About 98 per cent respondents support this opinion. The presence of arsenic in deep tubewell is comparatively low but it is very much costly to set up. That's why people are using shallow tubewell water for drinking and cooking purpose. It becomes very difficult for them to boil pond or canal water. No person use filteration for potable or pure or arsenic free water.

Over all water quality is bad but it is good for bathing and washing. Water quality of odour is nothing, taste is natural and colour is clear but some exceptional case, turbid variable is visible.

7.11. Findings:

- Male patients are more sufferer than female patients in arsenicosis.
- Social problems (separation, maladjust) are not mentionable but divorce case has been found and marriage problems has also been present.
- Most of the arsenicosis patients have faith in rural treatment (spinach, exorcising and talisman).
- The major social and psychological problems like marriage, divorce, separation, loneliness etc. case of arsenicosis victims will be accelerated with increase of prevalence rate of arsenicosis patients.
- Most of the patients thing that arsenicosis is curse from Allah or it is a contagious disease.
- Main source of drinking water is tubewell.
- The study area is highly affected with arsenic contamination in groundwater.
- About 99 per cent people are taking arsenic contaminated water everyday and are at risk of arsenicosis disease.

7.12. Recommendation and Conclusion

The arsenic problem in the study area is worsening day by day. The most of the people are suffering from arsenicosis. People do not get arsenic-free drinkable water. So, they are bounded to use arsenic contaminated water. Their sufferings know no bound. The parents become unable to give their daughters in wedding because such patients are not desirable to any suitor. The rate of illness and mortality increase in society. The affected persons lose their dexterity as they gradually become weak. Previously, it was told that another name of water is "life" or "water is the elixir of life." But now-a-days it adds if the water is free from germs and arsenic. So, it should take the following steps:

- To identify arsenic contamination-free tubewells it is necessary to test all the tubewells in affected areas, which can be done by using the arsenic field test kit.
- For supply of safe water as an immediate measure, deep and shallow tubewells with proper sealing of the drilling gap may installed in safer aquifers.
- People should be encouraged to use the tubewells that are not contaminated with arsenic.
- If an arsenic contamination-free tubewell is not available, rain water collection and preservation for year round use. To retard percolation of water, polythene sheets may be used for the purpose.

- The arsenic free water has to be supplied free of cost to the overwhelmingly poor villagers who may not be able to pay for the cost of the process.

- The people are to be accustomed to use arsenic removal methods at least for drinking and cooking purposes.

- Government needs to constantly monitor water quality from tubewells. The emerging crisis could have been averted had government or aid agencies taken the extra effort to conduct periodic chemical analyses of tubewell-water samples. After fluoride and arsenic contamination, who knows which chemical's turn in next.

- The fundamental chemical processes should to be used for removing arsenic from water.

- Personally/Aid agencies, on their part, can not longer afford to rush into tubewell installation sets up/programs anywhere in the study area without conducting geological surveys and environmental-impact assessments.

- Tubewells have been proven to be contaminated by arsenic, people should use coagulations or 3 to 4 pitcher filters or sands filter compulsorily in drinking water from such wells or bank of the river, pond and lake.

- The water quality has to be constantly monitored and the appropriate dosage for the use of chemicals and operating parameters changed, if necessary. This requires well trained chemist.

- The "*Zakat*" that is collected can be used for arsenic removing.

- The philathropic people can come forward to help the poor village people and there could be some filters provided for the community use.

- Government needs to encourage the people of study area to cut down on their dependence on rice. Paddy cultivation consumers enormous amounts of water. They should be given incentives for growing other crops like wheat which consume less water.

- Removal of arsenic possible by using fern and soil. The scientists are of the opinion that a kind of plant by name of Brake Fern (Scientific name **Stares Vitata**) (looks like Dheki Shak) is capable of removing arsenic from soil and water (Dr. Lena Ma, the Florida University researcher) (Dr. Rahim M.A. The Independent, 15.03.2002).

- Many researcher recommended for boiling water but I do not recommend it because boiling 20/30 litres of water everyday involves large fuel cost and may damage the village environment if wood and other combustibles are daily used by the villagers for large amount of surface water.

- The "Imam" can play an important role in this effort. Every Friday he can addressed the people (the Musalli) about arsenic, arsenicosis, removal of arsenic etc.

- For more awareness of the people we can use press and electronic media. Bill Board, Bell Sign. Projection, Flash card, Posters, Leaflets and Stickers for personally, nationally and internally.

- Newspapers, radio and television can play a great role in this effort. Just like during cyclones or floods special messages are propagated in newspapers, radio, and TV these media can broadcast for the public that

wherever you suspect groundwater contamination by arsenic, please use filter and if you drink surface water please boil it and you will be free from arsenic scourge.

- The problem of cotnamination of ground water in the area is a product Geo-environment and to change this is beyond the capability of human being. Now we are to follow the saying of Francis Becon, "Nature is to command and must be obeyed."

Further studies are required for mitigate the arsenic and arsenicosis propblem.

Conclusion

This study is done to assess the knowledge of community people regarding arsenic contaminated water in selected rural area of Bangladesh. Side by side, chemical analysis and comparative analysis with other chemical parameters, geo-environmental analysis, soil analysis, the relationship of socio-demographic, socio-economic characteristics, social, physical and psychological/clinical problem, drinking water habits and variables like age, occupation, income and expenditure, social and educational status, source of drinking water etc. is also observed. It is very difficult to come to a decision from this small scale study, because the sample size is small. However, following conclusion can be made.

Bangladesh is a river irrigated country through which three major international rivers flow. The water resources condition of Bangladesh is mainly dependent upon the Ganges-Brahmaputra-Meghna river system originated from India. It works as a retention basin of excess water carried

by the river system for final discharge in the Bay of Bengal. The Ganga-Padma and Brahmaputra-Jamuna river systems drain a huge area of land and since 1975 the huge amount of upstream withdrawal at Farakka of India from the Ganges create a number of problems in the downstream area of the Ganges delta region. Arsenic problem is one of them.

In the lower reach of the river in Bangladesh, water submerges one third to half of the country each year depending on the intensity of floods. In the low-lying flood plains, the water becomes nearly stagnant and the fine-grained silt and clays, rich in arsenic are deposited.

Arsenic contamination is now considered as a great threat to the future generation of the study area as well as the whole country. The arsenic contamination in groundwater is due to some geochemical changes. "Green Revolution" has been promoted to increase rice production withdrawing large quantities of underground water, (according to Dr. Chakraborti it begins since late 1970s). As a result, water levels in tubewell drop, allowing oxygen to enter the ground and touching off a reaction that leaches out arsenic from pyrite in the soil. The actual mechanism, however, is yet to be identified with certainly. In the area, both categories of tubewells (shallow and deep) are badly reach in arsenic. Comparatively deep tubewells show low arsenic than shallow tubewells and outside polder's arsenic is higher than inside polders.

The area of study is a part of the Ganges-Brahmaputra-Meghna flood plain as well a part of gravity low area consequently the coastal part of Bay of Bengal which is and was an area of active deposition. Hydrochemical relationships observed with the study area support the "reduction" theory for

the release of arsenic in groundwater in Bangladesh, which states that arsenic is released and mobilized by the reductive dissolution of iron-oxyhydroxides in reducing environment of the aquifer. Positive correlation of arsenic with iron and bicarbonate highlights on that fact. It emphasizes the fact and overshadows the preliminary hypothesis of "pyrite oxidation". The depth of the tubewell and polder plays a significant role on arsenic. In one sample value of arsenic is very low (0.005- mg/l) and another is very high (1.33 mg/l). Here depth and polder (outside) plays a vital role in the concentration of arsenic. The sample of low aquifer regions is mostly affected with arsenic contamination. Deep tubewell water is also contaminated with arsenic due to geochemical and geophysical condition of the soil layer.

Field Kit test and Laboratory methods are used for analyzing samples. Kit method shows zero or high level of arsenic whereas, laboratory method shows tolerable level of arsenic. This preliminary findings showed that kit can serve as a first screening of the samples and the laboratory method will reveal the exact level of arsenic content of the samples.

The method shows a reasonable accuracy in identifying safe and unsafe wells. The variation of arsenic may be due to the interference of iron present in water. However, the method seems very good in quick assessment of the risk of the hazard and helps in planning sampling strategy. The "field-kit" is also suitable for detecting safe wells at low cost in the rural areas.

The absence of organic matter and presence of coarse-grained aquifer materials, and again, the presence of coarse grained sands with gravels and absence of organic matters may be the cause of arsenic. Because the

surrounding floodplain deposits are characteristically of fine grained sands and high organic matters. Sedimentation and depositional pattern play an important role on the variability of arsenic concentration.

Soil samples contain arsenic within Bangladeshi standard value. But some samples exceed Japanese standard value. In this study area soil contains very high level arsenic.

Range of temperatures prevailing in the surface may be congenial to dissolve the arsenic to extent. There is a seasonal variation in vertical movement of groundwater which enhance or retards the contents of arsenic in the groundwater.

The Ramganj upazila is highly affected with arsenic contamination in groundwater. The consumers of 99 per cent of the tubewells are taking arsenic contaminated water every day and are at risk of developing arsenicosis including cancer. During the study period most of the users of arsenic contaminated water are suffering from arsenicosis and most of them were in first and second stage. Arsenic can be accumulated in almost all vital organs of the body namely liver, kidney, heart, lungs, brain, keratosis, melanosis, weakness, nail loss, hair-delayed loss, pigmentation, capillary flush, headache, pericarditis are also present. The arsenicosis patients have also been suffering from a mental agony for loss of natural appearance, fear of getting gangrene, no remedy is known to anyone and mental anxiety.

Arsenic problem generated problem in public health situation as well as social and personal life. Men or girls get disinterred in marrying the girls or boys who have signs of arsenicosis due to various reasons e.g. such a

girl/boy would cause unhappy family condition, such girls/boys would be sexually malfunctioned.

Arsenicosis has affected adversely the overall income generation activities. Most of the patients take rural treatment.

At the end it is to say there is no reason to be panic regarding the problem. Due to environmental conditions it had been, is and will be in time immemorial. Now the problem is known to us and we are to decide how we can have safe water for drinking and cooking purpose.

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Acronyms

BANSDOC – Bangladesh National Scientific Technical Documentation centre.

BAPA – Bangladesh Poribesh Andolon

BCSIR – Bangladesh Council of Scientific and Industrial Research

DTW – Deep Tubewell

FASC – The Fluoride and Arsenic Society of China.

FEJB – Forum of Environmental Journalists of Bangladesh.

GSB – Geological survey of Bangladesh

ICDDR, B – International centre for Diarrhoea Disease Research, Bangladesh.

IEDCR – Institute of Epidemiology Disease Control and Research.

NIPSOM – National Institute of Preventive and Social Medicine

NRC – National Research council, Washington DC.

Protection Agency

SAARC – South Asian Association of Regional co-operation.

SAIC – SAARC Agricultural Information Centre.

SRDI – Soil Resources Development Institute

STW – Shallow Tubewell

UNDP – United Nations Development Program.

USA – United States of America.

USEPA – United States Environmental

USGS – United States Geological Survey

WHO – World Health Organization

AS – Arsenic

MCL – Maximum contaminant level

Mg/l – Micrograms per Litre

PPb – Parts per billion

SARS – Severe Acquired Respiratory Syndrome.

SDDC – Silver diethyldithiocabamate

TAS – Total Arsenic

APPENDICES

Appendix-A

Table – 1.1: Arsenic Contaminated Region and Other Criteria of Bangladesh

DIVISION	DISTRICT	UPAZILA	# of Union	# of village	twtested	twoperative	as_safe	as_conta	perc_conta	hh	pop_surveyed	pop_female	pop_male	PATIENTS	Stekeholder	PAT_MALE	PAT_FEMALE
Dhaka	Dhaka	Dhamrai	16	421	37958	37848	34591	2841	7.506341154	36725	264924	139754		5	Unicef		
Dhaka	Dhaka	Dohar	7	87	14143	13705	2702	11003	80.28456768	24590	156819	79999	76820	94	BAMWSP	45	49
Dhaka	Dhaka	Keraniganj	12	654	39183	38624	35627	2420	6.265534383	36286	293943	134626		3	Unicef		
Dhaka	Dhaka	NAWABGANJ	14	662	39866	35818	20454	15364	42.89463398	39866	16	12	4	0	WorldVision	0	0
Dhaka	Faridpur	Alfadanga	6	118	7155	7131	3923	3208	44.98667789	21257	135407	64095	71312	96	BAMWSP	41	55
Dhaka	Faridpur	Bhanga	12	236	21475	20375	1796	18514	90.86625767	21475	128001	93861		0	Unicef		
Dhaka	Faridpur	Boalmari	12	273	17197	17000	10941	6059	35.64117647	47535	253005	115533	137472	176	BAMWSP	73	103
Dhaka	Faridpur	Char Dhadrasan	4	85	7557	7494	7029	465	6.204963971	16556	84404	38935	45469	5	BAMWSP	1	4
Dhaka	Faridpur	Faridpur Sadar	12	932	66784	66708	44608	22100	33.12945973	66784	0	0	0	0	WorldVision	0	0
Dhaka	Faridpur	Madhukhali	9	212	12914	12693	8685	4008	31.57645947	39660	202630	94215	108415	230	BAMWSP	120	110
Dhaka	Faridpur	Nagarkanda	18	347	24898	24414	9072	15342	62.84099287	68534	409728	183320	226408	343	BAMWSP	170	173
Dhaka	Faridpur	Sadarpur	9	293	18780	18554	9581	8973	48.36153929	41031	250891	110353	140538	52	BAMWSP	19	33
Dhaka	Gazipur	Kaliganj	6	105	19090	18739	18654	85	0.453599445	42966	222583	104185	118398	6	BAMWSP	3	3
Dhaka	Gopalganj	Gopalganj Sadar	23	207	15234	14572	915	13657	93.72083448	47924	375843	154057	221786	181	BAMWSP	106	75
Dhaka	Gopalganj	Kotwalipara	12	179	7870	6889	1663	5226	75.86006677	44100	239722	116207	123515	135	BAMWSP	75	60
Dhaka	Gopalganj	Muksudpur	17	474	35170	17326	6885	10441	60.26203394	35170	0	0	0	0	WorldVision	0	0
Dhaka	Gopalganj	Tungipara	5	59	3295	2877	523	2354	81.82134168	17263	98768	46119	52649	135	BAMWSP	58	77
Dhaka	Gopalganj	Kashiani	14	161	16322	15980	6497	9483	59.34292866	47443	264066	125313	138753	120	BAMWSP	63	57
Dhaka	Jamalpur	Bakshiganj	8	225	26182	25504	24549	972	3.811166876	24190	190763	84859	105904		Unicef		
Dhaka	Jamalpur	Jamalpur Sadar	15	363	50399	49035	48241	793	1.617212195	47899	364385	161246	203139		Unicef		
Dhaka	Jamalpur	Sharishabari	8	164	27532	27332	25899	1433	5.24293868	60656	367566	166611	200955	86	BAMWSP	39	47
Dhaka	Kishoreganj	Austagram	7	57	4796	4291	3828	463	10.79002564	4670	43345	19199	24146		Unicef		
Dhaka	Kishoreganj	Bajitpur	11	174	11895	11682	10008	1674	14.32973806	39316	197906	94026	103880	14	BAMWSP	4	10
Dhaka	Kishoreganj	Bhairab	6	67	11787	11763	8348	3415	29.0317096	27982	172716	80901	91815	375	BAMWSP	129	246
Dhaka	Kishoreganj	Hossainpur	6	102	5860	5476	5203	273	4.985390796	48882	228608	106298	122310	31	BAMWSP	22	9

Dhaka	Kishoreganj	Itna	9	218	7588	7188	5284	1904	26.4885921	7450	60078	26450	33628		Unicef		
Dhaka	Kishoreganj	Karimganj	11	183	10532	10224	8428	1796	17.56651017	60453	302342	143759	158583	14	BAMWSP	8	6
Dhaka	Kishoreganj	Kishoreganj	11	197	8954	8643	7892	751	8.689112577	59917	268924	126019	142905	6	BAMWSP	2	4
Dhaka	Kishoreganj	Kuliarchar	6	97	13946	13656	10771	2885	21.12624487	29236	147472	69850	77622	43	BAMWSP	17	26
Dhaka	Kishoreganj	Nikli	6	111	3465	2963	2166	797	26.89841377	3011	21954	10097	11857		Unicef		
Dhaka	Kishoreganj	Pakundia	10	153	18753	18394	17810	584	3.174948353	53120	269056	125358	143698	60	BAMWSP	21	39
Dhaka	Madaripur	Kalkini	15	190	11931	11164	3902	7262	65.04836976	64875	334771	155890	178881	91	BAMWSP	49	42
Dhaka	Madaripur	Madaripur	15	203	21606	21079	4439	16640	78.94112624	63549	348214	165869	182345	286	BAMWSP	93	193
Dhaka	Madaripur	Rajoir	10	196	13763	13003	3158	9803	75.39029455	11937	46075	40516		0	Unicef		
Dhaka	Madaripur	Shib Char	19	266	29978	29395	16150	13173	44.81374383	17907	69169	60372		0	Unicef		
Dhaka	Manikganj	Daulatpur	8	184	14978	14565	12799	1766	12.12495709	36359	193540	90094	103446	20	BAMWSP	14	6
Dhaka	Manikganj	Ghior	7	174	14186	13692	9531	4159	30.37540169	13328	115347	50179	65168		Unicef		
Dhaka	Manikganj	Harirampur	13	242	13742	13275	4915	8360	62.97551789	35686	172413	80045	86368	204	BAMWSP	84	120
Dhaka	Manikganj	Saturia	9	218	17878	17592	15371	2221	12.62505684	16895	107297	50315	56982		Unicef		
Dhaka	Manikganj	Shibalaya	7	229	12390	12013	7366	4647	38.68309332	36202	189378	89034	100344	59	BAMWSP	37	22
Dhaka	Manikganj	Singair	11	192	19475	18970	11298	7672	40.44280443	41978	284261	136449	147812	12	BAMWSP	8	4
Dhaka	Munshigonj	Gazaria	8	118	8318	8880	1584	7296	82.16216216	25557	147600	71204	76396	220	BAMWSP	93	127
Dhaka	Munshigonj	Lohajang	10	100	10228	9878	895	8983	90.93946143	31587	166790	82653	84137	107	BAMWSP	34	73
Dhaka	Munshiganj	Munshiganj Sadar	11	267	18777	18249	14393	3707	20.3[illegible]4183	18152	136000	61755		0	Unicef		
Dhaka	Munshiganj	Serajdikhan	14	186	18957	18221	9759	8462	46.44091982	18957	66040	61802		0	Unicef		
Dhaka	Munshigonj	Sreenagar	14	150	18523	17827	3706	14121	79.21130869	47905	261006	125728	135278	110	BAMWSP	46	64
Dhaka	Munshigonj	Tongibari	12	148	12652	12078	2390	9688	80.21195562	42131	240425	107778	132647	363	BAMWSP	161	202
Dhaka	Mymenshingh	Dhobaura	7	346	8748	8554	6488	2066	24.1524433	8748	91194	41376	49818	121	WorldVision	42	79
Dhaka	Mymensingh	Gauripur	11	316	27861	27211	25924	1289	4.737054868	26625	234386	101318	133068		Unicef		
Dhaka	Mymenshingh	Haluaghat	12	410	27612	27558	24158	3400	12.33761521	27614	213188	94862	118326	0	WorldVision	0	0
Dhaka	Mymensingh	Mymensingh Sadar	34	347	58421	55563	54753	814	1.46500369	53759	602254	269528	332726		Unicef		
Dhaka	Mymensingh	Nandail	13	316	15964	15171	13967	1204	7.936194054	15245	133103	59833	73270		Unicef		
Dhaka	Mymenshingh	Phulpur	20	766	101388	101036	97778	3258	3.224593214	100562	823312	362374	460938	68	WorldVision	26	42
Dhaka	Narayanganj	Araihazar	12	297	30326	29151	19722	9429	32.34537409	70659	402022	181384	220638	384	BAMWSP	199	185
Dhaka	Narayanganj	Sonargaon	11	365	25233	24539	9128	15411	62.80207017	25233	64492			323	Unicef		
Dhaka	Narayanganj	Bandar	6	197	16581	16479	10563	5828	35.36622368	17219	112652	52741		0	Unicef		

Dhaka	Narsingdi	Belabo	7	92	22896	22878	20264	2614	11.42582394	32445	190946	91797	99149	266	BAMWSP	127	139
Dhaka	Narsingdi	Manohardi	11	210	35889	35662	32173	3259	9.138578879	36866	239014	108985		0	Unicef		
Dhaka	Narsingdi	Narsingdi	15	235	30797	30443	24090	6353	20.86850836	82440	433819	195980	237839	168	BAMWSP	79	89
Dhaka	Narsingdi	Palash	5	159	22403	21647	20759	413	1.907885619	21078	176611	79486		7	Unicef		
Dhaka	Narsingdi	Raipur	24	235	46310	45360	36744	8616	18.99470899	97440	502188	239308	262880	404	BAMWSP	200	204
Dhaka	Narsingdi	Shibpur	9	271	45564	43331	40195	2036	4.698714546	38411	256182	115914		1	Unicef		
Dhaka	Netrokona	Atpara	7	171	4654	4527	3294	1233	27.23658052	31906	172936	82770	90166	223	BAMWSP	107	116
Dhaka	Netrokona	Durgapur	8	490	19096	19068	15906	3162	16.58275645	19354	330038	154344	175694	612	WorldVision	322	290
Dhaka	Netrokona	Khaliajuri	5	62	1584	1374	690	684	49.78165939	16848	94649	43988	50661	41	BAMWSP	28	13
Dhaka	Netrokona	Kalmakanda	8	686	13128	13100	9348	3752	28.64122137	13128	241562	115452	126110	0	WorldVision	0	0
Dhaka	Netrokona	Kendua	13	252	20327	19561	13418	6143	31.40432493	63531	323020	154210	168810	122	BAMWSP	56	66
Dhaka	Netrokona	Madan	8	98	3275	3180	2291	889	27.95597484	31119	132612	63616	68996	3	BAMWSP	3	0
Dhaka	Netrokona	Mohanganj	10	172	4951	4513	2871	1642	36.38378019	34113	172836	80179	92657	30	BAMWSP	17	13
Dhaka	Rajbari	Goalandaghat	5	185	10393	10219	9608	611	5.979058616	22027	123685	58351	65334	26	BAMWSP	12	14
Dhaka	Rajbari	Pangsha	17	308	18872	18530	16999	1531	8.262277388	70304	360764	164425	196339	352	BAMWSP	157	195
Dhaka	Rajbari	Rajbari	17	231	21606	21249	18160	3089	14.53715469	56725	297689	137352	160337	448	BAMWSP	207	241
Dhaka	Shariatpur	Bhedarganj	12	386	14223	13681	10202	3479	25.42942767	47183	253424	119773	133651	109	BAMWSP	53	56
Dhaka	Shariatpur	Damudya	8	119	4853	4295	2318	1977	46.03026775	25531	125947	61239	64708	59	BAMWSP	29	30
Dhaka	Shariatpur	Gosairhat	7	198	5793	5441	2776	2665	48.97996692	33576	183746	84968	98778	62	BAMWSP	33	29
Dhaka	Shariatpur	Naria	15	218	15703	14824	8265	6559	44.24581759	60342	335546	150758	184788	281	BAMWSP	110	171
Dhaka	Shariatpur	Shariatpur Sadar	14	182	9728	9011	3304	5707	63.33370325	35721	179646	86233	93413	260	BAMWSP	112	148
Dhaka	Shariatpur	Zanjira	12	180	21797	21485	19018	2467	11.4824296	44155	217545	102474	115071	33	BAMWSP	12	21
Dhaka	Sherpur	Nakla	9	147	33988	33009	30897	2075	6.286164379	29371	274872	116612	158260		Unicef		
Dhaka	Sherpur	Nalitabari	13	150	24542	22165	15144	7021	31.67606587	59912	256950	125541	131409	392	BAMWSP	176	216
Dhaka	Sherpur	Sherpur Sadar	8	122	23976	23975	23429	545	2.273201251	23668	193927	79385	114542		Unicef		
Dhaka	Sherpur	Sreebardi	10	166	39757	39411	33632	5779	14.66341884	63090	340267	157465	182802	19	BAMWSP	7	12
Dhaka	Tangail	Basail	6	124	20830	20123	18057	2066	10.26685882	20089	132540	62297	70243		Unicef		
Dhaka	Tangail	Delduar	8	157	27516	27231	23469	3762	13.81513716	43674	262897	122600	140297	57	BAMWSP	34	23
Dhaka	Tangail	Mirzapur	14	243	40844	39531	34673	4857	12.28655992	39056	270443	124905	145538		Unicef		
Dhaka	Tangail	Nagarpur	12	237	38561	38222	35818	2404	6.289571451	58218	402426	180771	221655	23	BAMWSP	7	16
Dhaka	Tangail	Tangail Sadar	22	158	27191	25815	23810	2005	7.766802247	24028	171358	76505	94853		Unicef		

Chittagong	Brahmanbaria	Akhaura	6	147	10377	10165	10121	44	0.432857846	25027	126925	60809	66116	0	BAMWSP	0	0
Chittagong	Brahmanbaria	Bancharampur	16	142	20425	19816	5322	14484	73.09245055	17936	82022	66120		0	Unicef		
Chittagong	Brahmanbaria	Brahmanbaria	33	460	28782	28513	23987	4526	15.87346123	92249	486290	233420	252870	284	BAMWSP	139	145
Chittagong	Brahmanbaria	Kasba	10	243	20462	20168	16161	4007	19.86810789	53069	298549	142054	156495	113	BAMWSP	53	60
Chittagong	Brahmanbaria	Nabinagar	21	217	31654	29811	3969	25892	86.8538459	29669	105401	98444		0	Unicef		
Chittagong	Brahmanbaria	Nasirnagar	13	132	7882	7406	6908	498	6.724277613	52329	267460	128343	139117	146	BAMWSP	54	92
Chittagong	Brahmanbaria	Sarail	10	137	14908	14223	6437	7786	54.74231878	46273	335796	155269	180527	233	BAMWSP	101	132
Chittagong	Chandpur	Chandpur Sadar	14	104	12314	11679	2819	8860	75.86265947	63054	346382	162291	184088	343	BAMWSP	119	224
Chittagong	Chandpur	Faridgonj	16	156	27716	25236	372	24864	98.52591536	70998	475165	221218	253947	371	BAMWSP	138	233
Chittagong	Chandpur	Haim Char	6	48	3850	3606	478	3115	86.38380477	3647	50972	23852		0	Unicef		
Chittagong	Chandpur	Hajiganj	13	139	14398	13350	234	13116	98.24719101	40599	332825	137386	195439	552	BAMWSP	192	360
Chittagong	Chandpur	Kachua	18	253		17787	366	17419	97.93107326	44501					Unicef		
Chittagong	Chandpur	Matlab	19	315	23832	22151	3211	18940	85.50404045	71409	475879	237958	237921	466	BAMWSP	191	275
Chittagong	Chandpur	Shahrasti	9	176	16964	16498	226	16271	98.62407565	16320	134476	93512		0	Unicef		
Chittagong	Chittagong	Mirsharai	17	195	31436	31079	19934	11145	35.86022716	74112	519739	233792	285947	87	BAMWSP	34	53
Chittagong	Chittagong	Sitakunda	11	116	19313	18843	14191	4652	24.68821313	61877	439765	186896	252869	47	BAMWSP	12	35
Chittagong	Comilla	Barura	15	315	28095	26321	7457	18858	71.64621405	25320	203224	144777		0	Unicef		
Chittagong	Comilla	Brahmanpara	8	73	15286	14699	4983	9716	66.09973468	38756	228829	109281	119518	34	BAMWSP	18	16
Chittagong	Comilla	Burichang	8	168	20625	20368	16053	4315	21.18519246	56047	331634	153209	178425	30	BAMWSP	14	16
Chittagong	Comilla	Chandina	12	209	18393	17585	1696	15889	90.35541655	62610	391529	180260	211269	138	BAMWSP	63	75

Chittagong	Cumilla	Chauddagram	14	373	42301	40590	31768	8822	21.73441734	83023	456350	218565	237785	193	BAMWSP	76	117
Chittagong	Cumilla	Daudkandi	23	388	27677	26133	3326	22807	87.27279685	76095	490568	243582	246986	423	BAMWSP	210	213
Chittagong	Cumilla	Debidwar	16	198	30270	28916	6523	22393	77.44155485	85842	524924	243454	281470	49	BAMWSP	16	33
Chittagong	Comilla	Homna	14	227	19829	18848	5764	12982	68.87733447	15841	62490	55980		0	Unicef		
Chittagong	Cumilla	Laksam	22	535	42234	40170	8266	31904	79.42245457	96019	661866	322811	339055	1791	BAMWSP	775	1016
Chittagong	Comilla	Muradnagar	22	300	29098	28678	1969	26741	93.24569356	29098	270809	212134		0	Unicef		
Chittagong	Comilla	Nangalkot	11	290	27256	26497	15626	10871	41.02728611	63968	361499	171436	190063	735	BAMWSP	460	275
Chittagong	Comilla	Meghna	7	94	10155	9738	5153	4585	47.08359006	34153	175848	84234	91614	19	BAMWSP	11	8
Chittagong	Cox's Bazar	Ukhia	5	55	15461	15076	14850	226	1.499071372	25959	176416	81173	95243	15	BAMWSP	2	13
Chittagong	Feni	Dagan Bhuiyan	9	119	23756	23576	8214	15362	65.15948422	46999	321396	142211	179185	135	BAMWSP	47	88
Chittagong	Feni	Feni Sadar	16	147	31265	30824	14787	16037	52.0276408	67188	448236	205992	242244	305	BAMWSP	121	184
Chittagong	Feni	Sonagazi	9	130	16687	16681	6349	10332	61.93873269	16697	276345	109680		11	Danida		
Chittagong	Lakshmipur	Lakshmipur Sadar	18	312	35336	35333	11068	24268	68.68366683	35434	392991	166364		205	Danida		
Chittagong	Lakshmipur	Raipur	10	51	11867	10712	1454	9258	86.42643764	48797	270903	132709	138194	616	BAMWSP	278	338
Chittagong	Lakshmipur	Ramganj	13	145	19256	18094	4011	14083	77.83243064	48234	249519	123224	126295	787	BAMWSP	260	527
Chittagong	Lakshmipur	Ramgati	12	117	11293	11293	8030	3263	28.89400514	11310	225425	90754		23	Danida		
Chittagong	Noakhali	Begumgonj	26	479	53553	53553	5159	48394	90.36655276	53836	907413	360689		391	Danida		
Chittagong	Noakhali	Chatkhil	10	110	17226	16776	4870	11906	70.97043395	43862	246904	115199	131705	1034	BAMWSP	371	663
Chittagong	Noakhali	Companiganj	12	53	11623	11124	7972	3152	28.33513125	40164	236345	108086	128259	231	BAMWSP	97	134
Chittagong	Noakhali	Senbagh	9	111	19926	19334	5058	14276	73.83883314	51608	311647	148463	163184	1023	BAMWSP	316	707

Chittagong	Noakhali	Noakhali Sadar	21	366	26904	26887	14291	12596	46.84791907	26932	604130	243034		64	Danida		
Rajshahi	Bogra	Dhunat	10	211	30207	29917	27322	2595	8.673998061	62560	320536	145436	175100	134	BAMWSP	69	65
Rajshahi	Bogra	Gabtali	10	217	34239	33692	31226	2416	7.170841743	68324	296332	134357	161975	142	BAMWSP	62	80
Rajshahi	Bogra	Sariakandi	12	424	54918	54848	51066	3782	6.89542007	54918	0	0	0	0	WorldVision	0	0
Rajshahi	Bogra	Shibganj	12	412	40142	39459	37268	2191	5.5525989	81926	332223	155421	176802	62	BAMWSP	29	33
Rajshahi	Dinajpur	Birganj	11	180	32194	32120	32058	62	0.193026152	62443	317052	142154	174898	6	BAMWSP	5	1
Rajshahi	Gaibandha	Gobindaganj	18	399	43274	42902	39509	3393	7.908722204	103518	454311	205344	248967	97	BAMWSP	56	41
Rajshahi	Gaibandha	Palashbari	9	160	21014	20655	19331	1324	6.410070201	54196	240112	110599	129513	33	BAMWSP	13	20
Rajshahi	Gaibandha	Saitullapur	11	169	31349	31021	29036	1985	6.398891074	73051	338337	159442	178895	45	BAMWSP	20	25
Rajshahi	Gaibandha	Sundargaanj	15	182	40638	40233	37623	2610	6.48721199	107569	487231	226466	260765	63	BAMWSP	33	30
Rajshahi	Kurigram	Nageshwari	15	407	41923	41630	41434	196	0.470814317	82361	369441	175239	194202	35	BAMWSP	15	20
Rajshahi	Kurigram	Rajarhat	7	142	23060	22745	18198	4547	19.99120686	34948	180941	86261	94680	161	BAMWSP	86	75
Rajshahi	Kurigram	Rauinari	5	181	16312	16235	15617	618	3.806590699	37483	198503	91603	106900	78	BAMWSP	43	35
Rajshahi	Kurigram	Ulipur	13	175	35680	34924	25138	9786	28.02084526	68954	347752	168685	179067	213	BAMWSP	137	76
Rajshahi	Naogaon	Manda	14	252	18593	17792	17463	329	1.849145683	75884	288009	135581	152428	40	BAMWSP	17	23
Rajshahi	Naogaon	Porsha	6	229	3246	2811	2795	16	0.569192458	24377	127814	62400	65414	0	BAMWSP	0	0
Rajshahi	Natore	Bagatipara	6	139	11288	10831	9986	845	7.801680362	26298	124970	60722	64248	98	BAMWSP	51	47
Rajshahi	Natore	Lalpur	10	196	19461	18852	17007	1845	9.786760025	46447	232070	114182	117888	280	BAMWSP	117	163
Rajshahi	Chapai Nawabganj	Bholahat	4	84	4151	3961	3799	162	4.089876294	21372	94565	47400		0	WPP		
Rajshahi	Chapai Nawabganj	Gomastapur	8	298	7929	7558	6681	877	11.60359884	75121	288418	144514		15	WPP		
Rajshahi	Chapai Nawabganj	Nachole	4	214	3196	2765	2684	79	2.857142857	26576	129266	64540		0	WPP		
Rajshahi	Chapai Nawabganj	Chapai Nawabganj	15	404	39948	38852	26948	11842	30.47976938	100075	535571	269646		1142	WPP		
Rajshahi	Nawabganj	Nawabganj Sadar	14	132	19545	19046	13572	5474	28.74094298	63027	346263	168494	177769	499	BAMWSP	240	259
Rajshahi	Chapai Nawabganj	Shibganj	16	382	40591	39859	32281	7581	19.01954389	99621	533162	260483		665	WPP		
Rajshahi	Pabna	Bera	8	166	14533	14282	6779	7503	52.53465901	38482	279055				Unicef		
Rajshahi	Pabna	Ishwardi	10	91	16098	15212	13603	1609	10.57717591	23694	196613	84450	112163	88	BAMWSP	44	44
Rajshahi	Pabna	Santhia	11	196	18112	17951	16138	1813	10.09971589	60722	278369	128373	149996	98	BAMWSP	36	62
Rajshahi	Pabna	Sujanagar	10	172	20359	19872	16107	3765	18.94625604	40374	281309	127304	154005	271	BAMWSP	142	129

Rajshahi	Rajshahi	Bagha	7	143	16511	16203	14846	1350	8.331790409	36219	180263	88904		283	WPP		
Rajshahi	Rajshahi	Baghmara	18	369	27145	24398	22378	2016	8.262972375	85357	341400	168312		10	WPP		
Rajshahi	Rajshahi	Boalia	1	5	447	411	358	53	12.89537713	2636	10691	5305		0	WPP		
Rajshahi	Rajshahi	Charghat	6	73	12520	12292	11124	1168	9.502115197	33610	210858	90627	120231	138	BAMWSP	69	69
Rajshahi	Rajshahi	Charghat	6	157	16136	15651	14661	942	6.018784742	47911	203580	101120		119	WPP		
Rajshahi	Rajshahi	Durgapur	7	126	11495	10849	10600	249	2.295142409	43652	169820	83595		44	WPP		
Rajshahi	Rajshahi	Godagari	9	488	11998	11593	11432	159	1.371517295	71031	314117	155799		10	WPP		
Rajshahi	Rajshahi	Mohanpur	6	183	6803	5482	4933	544	9.923385626	37047	150874	74971		4	WPP		
Rajshahi	Rajshahi	Paba	9	311	18384	15918	14516	1399	8.788792562	58261	258960	130339		36	WPP		
Rajshahi	Rajshahi	Puthia	6	186	17748	17351	16752	599	3.452250591	45918	195914	95429		14	WPP		
Rajshahi	Rajshahi	Tanore	7	207	5442	4595	4593	3	0.065288357	43151	179382	90394		1	WPP		
Rajshahi	Rangpur	Pirgachha	9	185	35018	34624	31145	3479	10.04794362	74802	409375	183365	226010	296	BAMWSP	149	147
Rajshahi	Sirajganj	Belkuchi	6	110	26489	26195	24633	1562	5.962970032	55112	288436	130347	158089	95	BAMWSP	52	43
Rajshahi	Sirajganj	Kamarkhanda	4	92	10201	10139	9303	836	8.245389092	24024	124737	57289	67448	40	BAMWSP	16	24
Rajshahi	Sirajganj	Kazipur	12	171	32728	32294	31229	1065	3.297826222	59948	307346	140727	166619	84	BAMWSP	43	41
Rajshahi	Sirajganj	Raiganj	9	252	26843	26274	20541	5733	21.82005024	58076	314026	147019	167007	226	BAMWSP	96	130
Rajshahi	Sirajganj	Shahjadpur	14	229	28785	28467	26047	2420	8.501071416	92136	429516	198485	231031	34	BAMWSP	11	23
Rajshahi	Sirajganj	Sirajganj	10	234	30514	30117	28334	1783	5.92024438	66574	320269	147951	172318	59	BAMWSP	27	32
Rajshahi	Sirajganj	Tarash	12	774	34590	34500	34334	166	0.48115942	34590	0	0	0	0	WorldVision	0	0
Khulna	Bagerhat	Bagerhat	10	179	13302	12440	4188	8252	66.33440514	55918	289165	129021	160144	89	BAMWSP	29	60
Khulna	Bagerhat	Chitalmari	7	104	6506	5775	1044	4731	81.92207792	32589	152058	73127	78931	72	BAMWSP	26	46
Khulna	Bagerhat	Fakirhat	8	82	12859	12218	4098	8120	66.45932231	32754	156731	71499	85232	244	BAMWSP	114	130
Khulna	Bagerhat	Kachua	7	94	4833	4518	2425	2093	46.32580788	24894	109068	52019	57049	3	BAMWSP	2	1
Khulna	Bagerhat	Mollahat	7	97	6870	6762	1426	5336	78.91156463	29681	146810	69182	77628	103	BAMWSP	50	53
Khulna	Bagerhat	Mongla	11	178	9	9	9	0	0	20	182	74	108	0	WorldVision	0	0
Khulna	Bagerhat	Morrelganj	16	182	6165	5408	3990	1418	26.2204142	78133	350472	166681	183791	50	BAMWSP	17	33
Khulna	Bagerhat	Rampal	10	130	3038	2790	1776	1014	36.34408602	40180	165867	80026	85841	16	BAMWSP	4	12
Khulna	Bagerhat	Sarankhola	4	44	1243	952	830	122	12.8[illegible]2605	28632	123524	59627	63897	12	BAMWSP	5	7
Khulna	Chuadanga	Alamdanga	14	241	35589	34133	19434	14699	43.06389711	89824	398727	189517	209210	400	BAMWSP	201	199
Khulna	Chuadanga	Chuadanga	7	128	23703	23312	18573	4739	20.32858614	48905	214394	101713	112681	164	BAMWSP	75	89
Khulna	Chuadanga	Damurhuda	8	147	39929	37945	28088	9545	25.15482936	28904	95598	82941		0	Unicef		

Khulna	Chuadanga	Jibannagar	5	112	18303	17923	15605	2368	13.17531853	34523	166634	75674	90960	41	BAMWSP	13	28
Khulna	Jessore	Abhaynagar	9	128	18894	18356	15500	2856	15.5589453	58107	281905	129699	152206	149	BAMWSP	64	85
Khulna	Jessore	Bagherpara	9	180	20765	20047	17104	2943	14.68050082	46126	232351	106169	126182	71	BAMWSP	39	32
Khulna	Jessore	Chowgachha	11	167	24931	24204	18948	5256	21.71541894	52207	253457	113571	138886	275	BAMWSP	156	119
Khulna	Jessore	Jhikargachha	10	176	23753	21748	10230	11518	52.96119183	23753	54303			232	Unicef		
Khulna	Jessore	Keshabpur	9	143	19351	18730	8336	10394	55.49386012	61772	267689	125464	142225	270	BAMWSP	165	105
Khulna	Jessore	Jessore Sadar (Kotwali)	19	388	78102	70014	58234	11763	16.80092553	67614	525819	216493	309326		Unicef		
Khulna	Jessore	Manirampur	17	248	35330	34799	16917	17888	51.40377597	34307	241317	170156		0	Unicef		
Khulna	Jessore	Sharsha	11	177		33344	25478	7866	23.59045106						JICA & AAN		
Khulna	Jhenaidah	Harinakunda	8	130	18804	18270	17023	1247	6.825396825	41656	203676	91946	111730	33	BAMWSP	12	21
Khulna	Jhenaidah	Jhenaidah Sadar	17	270	30639	29949	27071	2878	9.609669772	69076	330723	151598	179125	66	BAMWSP	30	36
Khulna	Jhenaidah	Kaliganj	12	229	30241	29574	26716	2860	9.670656658	29244	176685	81342	95343		Unicef		
Khulna	Jhenaidah	Kotchandpur	5	77	10872	10724	9464	1260	11.74934726	25810	112224	51045	61179	42	BAMWSP	10	32
Khulna	Jhenaidah	Maheshpur	12	190	30892	30399	27043	3356	11.03983684	64402	310597	144781	165816	117	BAMWSP	52	65
Khulna	Jhenaidah	Shailkupa	14	247	23180	22383	21262	1121	5.008265201	63728	316520	147592	168928	56	BAMWSP	22	34
Khulna	Khulna	Batiaghata	7	151	3177	3138	2957	181	5.768005099	32462	150251	72064	78187	1	BAMWSP	1	0
Khulna	Khulna	Dacope	9	150	3982	3964	3420	544	13.7235116	3982	32616	13748	18868	2	WorldVision	0	2
Khulna	Khulna	Dumuria	14	223	9593	9066	6188	2878	31.74498125	60441	288556	138039	150517	3	BAMWSP	3	0
Khulna	Khulna	Dighalia	6	48	7737	7181	4997	2184	30.41359142	29358	151557	71384	80173	263	BAMWSP	151	112
Khulna	Khulna	Paikgachha	11	214	13070	12148	4465	7683	63.2449786	54008	273160	128648	144512	40	BAMWSP	22	18
Khulna	Khulna	Phultala	4	36	8379	8174	6493	1681	20.56520675	26836	131099	62219	68880	30	BAMWSP	13	17
Khulna	Khulna	Rupsha	5	70	11035	10610	3751	6859	64.64655985	39497	191166	92177	98989	94	BAMWSP	24	70
Khulna	Khulna	Terokhada	6	95	5235	4731	1744	2987	63.13675756	23475	125154	59989	65165	30	BAMWSP	18	12
Khulna	Kushtia	Bheramara	9	78	14347	14209	10392	3817	26.86325568	28116	181414	80395	101019	189	BAMWSP	118	71
Khulna	Kushtia	Daulatpur	14	203	38229	37061	34554	2507	6.764523353	103825	464554	216774	247780	510	BAMWSP	228	282
Khulna	Kushtia	Kumarkhali	10	194	22179	21326	20263	1063	4.984525931	72490	361990	167061	194929	125	BAMWSP	69	56
Khulna	Kushtia	Kushtia	14	151	35240	34656	32171	2485	7.170475531	89591	398931	183108	215823	84	BAMWSP	25	59
Khulna	Kushtia	Mirpur	13	178	28651	27932	25507	2425	8.681798654	74848	337504	154546	182958	99	BAMWSP	36	63
Khulna	Magura	Magura	16	296	24471	23727	21332	2395	10.09398575	68873	345894	161291	184603	171	BAMWSP	91	80
Khulna	Magura	Mohammadpur	8	185	11987	11612	9490	2122	18.2741991	44328	227518	106346	121172	222	BAMWSP	113	109
Khulna	Magura	Salikha	7	121	13395	12507	10429	2078	16.61469577	34748	168418	79246	89172	172	BAMWSP	75	97

Khulna	Meherpur	Gangni	10	122	28179	27731	24339	3392	12.23179835	69906	338993	152183	186810	357	BAMWSP	181	176
Khulna	Meherpur	Meherpur	5	89	21645	21494	17972	3522	16.38596818	46604	203569	97096	106473	281	BAMWSP	161	120
Khulna	Meherpur	Mojibnagar	4	30	8314	8264	7210	1054	12.75411423	19975	89291	42564	46727	211	BAMWSP	149	62
Khulna	Narail	Kalia	13	200	12034	11116	2969	8147	73.29075207	11659	50437	34797		0	Unicef		
Khulna	Narail	Lohagara	12	218	18844	18307	9890	8417	45.97694871	57932	266534	126918	139616	85	BAMWSP	31	54
Khulna	Narail	Narail	13	231	15626	15039	11905	3134	20.83915154	49137	242895	114552	128343	124	BAMWSP	54	70
Khulna	Satkhira	Assasuni	11	236	12010	11136	3820	7316	65.69683908	62669	288227	136893	151334	286	BAMWSP	132	154
Khulna	Satkhira	Debhata	5	102	9067	8541	2002	6539	76.56012177	25791	132878	63795	69083	78	BAMWSP	41	37
Khulna	Satkhira	Kalaroa	12	136	17824	17008	889	16114	94.77151091	44109	212815	104832	107983	669	BAMWSP	312	357
Khulna	Satkhira	Kaliganj	12	253	12459	11913	8454	3459	29.03550743	62520	292872	137866	155006	26	BAMWSP	8	18
Khulna	Satkhira	Satkhira Sadar	17	590	56210	56172	30506	25666	45.69180375	56210	0	0	0	0	WorldVision	0	0
Khulna	Satkhira	Shyamnagar	12	203	2020	1666	1506	160	9.603841537	61562	326186	158142	168044	1	BAMWSP	0	1
Khulna	Satkhira	Tala	12	225	23150	22511	8199	14312	63.57780641	71566	328491	151025	177466	192	BAMWSP	82	110
Barisal	Barisal	Agailjhara	5	86	5291	4382	833	3549	80.99041534	32647	162348	78608	83740	64	BAMWSP	31	33
Barisal	Barisal	Babuganj	6	80	5809	4783	1114	3693	77.21095547	5322	17729	17302		1	Unicef		
Barisal	Barisal	Bakergonj	14	248	4516	4516	3560	956	21.16917626	4530	147782	65444		24	Danida		
Barisal	Barisal	Banaripara	8	77	3718	3251	1252	1999	61.48877269	30897	167467	79262	88205	115	BAMWSP	55	60
Barisal	Barisal	Gournadi	7	102	4899	4406	1635	2771	62.89151158	29256	166642	79466	87176	63	BAMWSP	25	38
Barisal	Barisal	Barisal Sadar	10	170	5218	5218	2516	2702	51.78229207	5230	149264	65133		42	Danida		
Barisal	Barisal	Mehendiganj	14	165	5656	5412	2147	3265	60.32889874	74214	397897	184020	213877	48	BAMWSP	22	26
Barisal	Barisal	Muladi	8	109	6955	6547	1254	5293	80.84618909	45643	248661	114077	134584	152	BAMWSP	48	104
Barisal	Barisal	Ujirpur	9	115	7281	6296	1603	4693	74.53939009	40754	264755	116123	148632	116	BAMWSP	69	47
Barisal	Bhola	Bhola	12	104	3937	3824	3657	167	4.367154812	68477	402159	189072	213087	11	BAMWSP	6	5
Barisal	Bhola	Lalmohan	10	81	2079	2047	2003	44	2.149487054	58023	329986	150541	179445	1	BAMWSP	0	1
Barisal	Jahalakhati	Jhalokati Sadar	9	174	5188	4473	2545	1928	43.10306282	29294	153999	75179	78820	75	BAMWSP	30	45
Barisal	Jahalakhati	Nalchity	11	141	4728	4589	3749	840	18.30464153	47851	265841	117844	147997	48	BAMWSP	19	29
Barisal	Pirojpur	Bhandaria	7	34	5212	4408	2819	1589	36.04809437	28403	154096	75019	79077	15	BAMWSP	8	7
Barisal	Pirojpur	Mathbaria	11	91	2218	1876	1627	249	13.27292111	55020	278188	131173	147015	26	BAMWSP	12	14
Barisal	Pirojpur	Nazirpur	8	142	5490	5251	3584	1667	31.74633403	41511	234025	107847	126178	14	BAMWSP	7	7
Barisal	Pirojpur	Pirojpur Sadar	10	166	6375	6375	4727	1648	25.85098039	6375	137216	57687		2	Danida		
Barisal	Pirojpur	Nesarabad	10	128	3751	3679	3493	186	5.055721663	52849	276501	127608	148893	5	BAMWSP	0	5

Sylhet	Habiganj	Ajmiriganj	5	86	2968	2916	2618	298	10.21947874	21173	131556	64340	67216	5	BAMWSP	0	5
Sylhet	Habiganj	Baniachang	15	289	9171	9011	7426	1585	17.5896127	56585	329796	162988	166808	21	BAMWSP	12	9
Sylhet	Maulvibazar	Kamalganj	10	215	8700	8586	8054	532	6.19613324	52886	276457	138599	137858	0	BAMWSP	0	0
Sylhet	Maulvibazar	Kulaura	17	492	22941	22234	18889	3345	15.0445264	56221	355390	173437	181953	43	BAMWSP	17	26
Sylhet	Maulvibazar	Maulvibazar	12	381	11436	10978	9767	1211	11.03115322	51680	309163	147362	161801	27	BAMWSP	18	9
Sylhet	Maulvibazar	Rajnagar	8	230	8566	8365	7804	561	6.706515242	39117	228441	114025	114416	8	BAMWSP	0	8
Sylhet	Sunamganj	Bishwambarpur	3	186	1340	1245	1230	15	1.204819277	13456	74806	35421	39385	10	BAMWSP	4	6
Sylhet	Sunamganj	Chhatak	14	559	10267	9628	8440	1188	12.33901122	56746	340637	163411	177226	61	BAMWSP	24	37
Sylhet	Sunamganj	Derai	10	250	3135	2964	2862	102	3.441295547	39008	188197	89027	99170	68	BAMWSP	27	41
Sylhet	Sunamganj	Dharmapasha	10	321	3016	2763	1526	1237	44.77017734	36792	193709	91644	102065	39	BAMWSP	20	19
Sylhet	Sunamganj	Dowara Bazar	7	318	5622	5335	4432	903	16.92596064	35071	180234	86939	93295	294	BAMWSP	150	144
Sylhet	Sunamganj	Jamalganj	5	172	1549	1412	1274	138	9.773371105	23609	130648	61271	69377	44	BAMWSP	21	23
Sylhet	Sunamganj	Sulla	4	120	1197	1059	1034	25	2.360717658	18017	95108	45783	49325	23	BAMWSP	11	12
Sylhet	Sunamganj	Sunamganj	17	489	5778	5496	4634	862	15.68413392	57056	325730	154813	170917	88	BAMWSP	38	50
Sylhet	Sylhet	Balaganj	14	480	9270	8659	6431	2228	25.73045386	47772	287242	137336	149906	112	BAMWSP	45	67
Sylhet	Sylhet	Beanibazar	11	183	17836	17290	16852	438	2.533256217	35127	204904	102019	102885	10	BAMWSP	5	5
Sylhet	Sylhet	Bishwanath	8	309	9585	9242	8815	427	4.620212075	34454	201891	94391	107500	36	BAMWSP	21	15
Sylhet	Sylhet	Companiganj	3	106	3833	3583	3135	448	12.5034887	17724	105562	48582	56980	30	BAMWSP	13	17
Sylhet	Sylhet	Golabganj	11	243	16625	16431	14684	1747	10.63234131	37283	344105	151840	192265	13	BAMWSP	6	7
Sylhet	Sylhet	Gowinghat	8	277	4869	4408	3804	604	13.70235935	35468	194537	92667	101870	16	BAMWSP	10	6
Sylhet	Sylhet	Kanaighat	9	257	4050	3426	2485	941	27.46643316	38178	223037	107322	115715	44	BAMWSP	19	25
Sylhet	Sylhet	Zakiganj	10	273	4940	4441	3633	808	18.19410043	38737	222260	105002	117258	107	BAMWSP	45	62

Source: BAWSP, 2004

APPENDIX-B

Sample No. _____

QUESTIONNAIRE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENT, UNIVERSITY OF DHAKA, BANGLADESH

GROUNDWATER ARSENIC CONTRAMINATION : A GEO-ENVIRONMENTAL ANALYSIS

STUDY AREA – RAMGANJ, LAKSHMIPUR

(This questionnaire survey will be used only for M. Phil fellow research.)

Name of the Respondent: _____

Address : _____

A. Respondent and his family Information:

1. Age :..... Years..... Months

2. Sex :
   - ❑ Male
   - ❑ Female

3. Education :
   - ❑ Degree and above
   - ❑ Higher Secondary
   - ❑ Secondary
   - ❑ Primary
   - ❑ Illiterate

4. Occupation :
   - ❑ Agriculture
   - ❑ Business
   - ❑ Employer (Govt/Private)
   - ❑ Housewife
   - ❑ Day Labourer
   - ❑ Students
   - ❑ Others

5. Monthly Income: Tk_____

6. Monthly Expenditure : Tk._____

7. Living Duration : _____ years _____ Months

8. Number of Family Members : _____

9. Number of Arsenicosis Patients: _____

10. Social Status:
    - ❑ High status
    - ❑ Medium status
    - ❑ Low status

11. Religion :
    - ❑ Islam
    - ❑ Hindu
    - ❑ Christian
    - ❑ Buddhist
    - ❑ Others

12. Marital Status :
    - ❑ Married
    - ❑ Unmarried
    - ❑ Widow
    - ❑ Widower
    - ❑ Others

B. Social/Physical/Mental Information of Respondents

B.1. Social Information:

Types of Problems	Yes	No	NA*
1. Marriage			
2. Divorce			
3. Separation			
4. Maladjust (cooking, eating etc)			
5. Physical Assault			
6. Being forced to go back to parents house			
7. Being ignored in school			
8. If yes, who does ❑ Teachers ❑ Students			
9. Unfair treatment in School			
10. Differential treatment in Service (Govt./Private)			
If yes ❑ Terminate ❑ Reduce Salary ❑ Others			
11. Non acceptance by Neighbour			
If yes ❑ Socially Boycott ❑ Economically Refuse ❑ Agricultural Retire			
12. Facing "Fatua" by Religious Leader			
13. Bad Behaviour by Doctor			
14. Disasterous help by Neighbour			
15. Boycott from Social function			

B.1. Physical Incidental Information:

1. Manifestation of Arsenicosis _____ Years _____Months _____days

2. Rural treatment for Arsenicosis:
   - ❑ Yes
   - ❑ No
   - ❑ NA*

3. Treatment Category:
   - ❑ Spinach
   - ❑ Exorcising and Incantation
   - ❑ Amulet and Talisman

4. Which following symptoms and signs are present:
   - ❑ Melanosis
   - ❑ Karatosis
   - ❑ Lecu Melanosis
   - ❑ Weakness
   - ❑ Burning of eyes
   - ❑ Diarrhoea
   - ❑ Cough
   - ❑ Couth with expectoration
   - ❑ Paresthesia
   - ❑ Pigmentation
   - ❑ Araemia
   - ❑ Hepatomegall
   - ❑ Splenomell
   - ❑ Capillary flush
   - ❑ Contact Dermatitis
   - ❑ Hair-delayed loss
   - ❑ Nail loss
   - ❑ Hyperpyraxia
   - ❑ Convulsion
   - ❑ Tremor
   - ❑ Coma
   - ❑ headache
   - ❑ Dysphagia
   - ❑ Vomiting
   - ❑ Weight loss
   - ❑ Jaundice
   - ❑ Oliguria
   - ❑ Pericarditis
   - ❑ Gangrene

B.3. Psychological Information:

1. Loneliness
   - ❑ Yes
   - ❑ No
   - ❑ NR*

2. Fell Distressed/Depression
   - ❑ Always
   - ❑ Sometimes
   - ❑ No distress

3. Being out of hearts by whom
   - ❑ Spouse
   - ❑ Sons & Daughters
   - ❑ Neighbour
   - ❑ NR*

4. Being out of sight of all
   - ❑ Yes
   - ❑ No
   - ❑ NR*

5. Privacy of this problem
   - ❑ Everybody knew easily
   - ❑ You have know everybody
   - ❑ Others

6. Behaviour of others
   - ❑ Satisfactory
   - ❑ Acceptable
   - ❑ Unsatisfactory
   - ❑ NR*

7. Spontaneous Mood
   - ❑ Very good
   - ❑ Good
   - ❑ Bad
   - ❑ Very bad

8. Curse of Nature/God/Allah
   - ❑ Yes
   - ❑ No
   - ❑ NR*

9. Arsenicosis is a Contagious Disease
   - ❑ Yes
   - ❑ No
   - ❑ NR*

C. Geo-environmental Information

1. Water Use:
   (a) Tubewells
      (i) Shallow
      (ii) Deep
   (b) Pond
   (c) Canal
   (d) River
   (e) Others
   Answer No. 2 if not a

2. Boiling water
   - ❑ Yes
   - ❑ No
   - ❑ NA

3. Cause of Arsenicosis:
   (a) Drinking of Deep Tubewells water
   (b) Drinking of Shallow Tubewells water
   (c) Others
   If Answer No. b

4. Do you stop Shallow Tubewells water
   - ❑ Yes
   - ❑ No

5. Reasons why do not stop Shallow Tubewells Water
   - ❑ No Alternative Way
   - ❑ Lack of knowledge
   - ❑ Distance of the safe tubewell water

6. Filteration of water
   - ❑ Yes
   - ❑ No
   - ❑ NA

7. Usable Water Quality Information

Variables	Very Good	Good	Bad	Very Bad	NR*
Drinking					
Cooking					
Bathing					
Washing					
Overall quality					

8. Water Pollution Information :

8.1. Water Quality (Odour)
   - ❑ High Intense
   - ❑ Usual
   - ❑ Not odour

8.2. Water Quality (Taste)
   - ❑ Natural
   - ❑ Unnatural
   - ❑ Not know

8.3. Water Quality (colour)
   - ❑ Clear
   - ❑ Turbid
   - ❑ Don't know

   NA* = Not Applicable
   NR* = No Response

Thanks for your kind co-operation and assistance.

APPENDIX- C

WATER QUALITY STANDARD FOR HOUSEHOLD USES

Substances	International/U.S.A. Standard in p.p.m.	Bangladesh Standard in p.p.m.
1. Total Solids	500/1500	1500
2. Colour	15 units	30 units
3. Taste	Unobjectionable	Unobjectionable
4. Ordour	Unobjectionable	Unobjectionable
5. Iron (Fe)	0.3/1.0	Max 5.0
6. Manganese (Mn)	0.1/0.5	0.5
7. Copper (Cu)	0.05/1.0	1.0
8. Zinc (Zn)	5.0/5.0	15.0
9. Calcium (ca)	75/200	200-500
10. Magnasium (Mg)	50/125	125
11. Nitrate	45/20	45 to 50
12. Sulphate (Se4)	200/250	400
13. Floride (F1)	2.0/1.50	1.0 to 2.0
14. Cloride (Cl)	250/250	Maximum 1000
15. Hardness as $CaCo_3$	250	250
16. pH range	7.0 to 8.5	6.5 to 9.2
17. Phenolic substances	0.001/0.001	0.002
18. Antimony	/0.05	
19. Arsenic	0.01/0.05	0.05
20. Barium	/1.0	
21. Bicarbonate	/5.0	
22. Boron	/20	
23. Cadmium	10 ppb/0.1	0.005
24. Cyanide	/0.2	
25. Lead	0.1/0.1	
26. Selenium	/0.01	
27. Silver	/0.05	
28. Sodium	/200	
29. Synthetic detergents	/0.5	
30. Chromium	/0.05	0.05

Source: Bangladesh Government

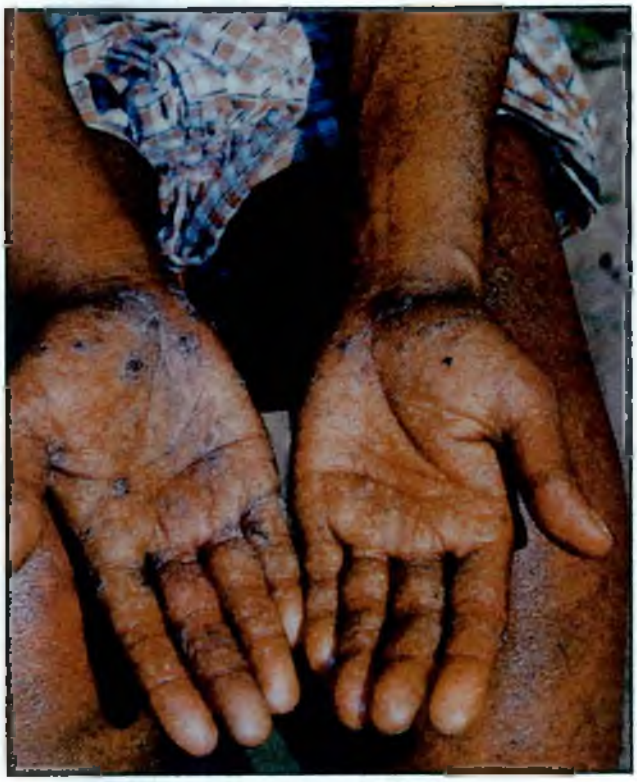
Appendix-D

LIST OF THE RESULTS OF TESTING WATER SAMPLES IN RAMGANJ AREA, LAKSHMIPUR DISTRICT.

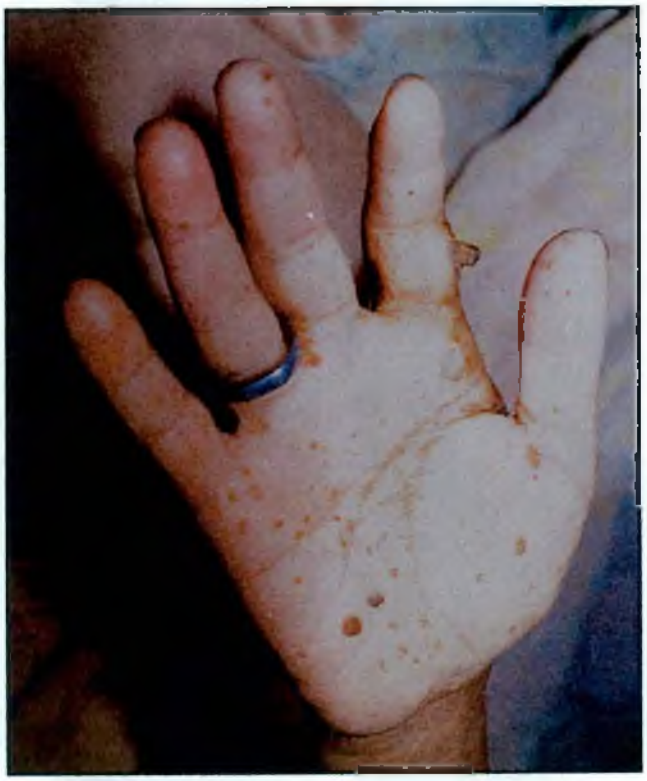
Name of Village	Serial No.	Wells Category	Depth (ft)	As (ppm)	DO	P[H]	BC	Tem.
Augonkhail	01	STW	26	0.34	2.8	8.2	19	30
	02	STW	26	0.85	3.00	8.4	32	28
	03	STW	30	0.65	3.2	8.00	35	28
	04	DTW	850	0.01	5.8	7.8	29	35
	05	DTW	780	0.005	1.7	8.0	23	24
	06	STW	20	0.25	1.75	8.3	18	25
	07	STW	36	0.04	2.3	8.1	21	28
Nandanpur	08	DTW	800	0.01	0.8	8.1	17	36
	09	STW	50	0.05	1.8	7.7	49	35
	10	STW	45	0.08	1.6	8.3	32	33
	11	DTW	800	0.01	1.9	9.0	18	34
Avirampur	12	STW	820	0.02	6.8	8.7	16	31
	13	STW	36	0.6	2.1	8.2	19	29
	14	STW	36	0.5	1.7	7.9	16	27
	15	STW	36	0.6	1.5	7.0	20	30
Rudrarampur	16	DTW	750	0.01	1.0	8.4	24	30
	17	STW	40	0.1	2.9	7.8	50	28
	18	STW	40	0.12	7.0	7.3	44	34
	19	STW	40	0.15	2.0	8.0	41	30
	20	STW	40	0.1	2.5	7.9	19	29
	21	DTW	850	0.01	5.0	7.5	20	31
	22	STW	42	0.08	3.2	7.8	21	28
	23	STW	-	0.45	2.9	7.7	18	32
	24	STW	60	0.2	2.8	7.5	20	29
Angarpara Ward No. 8	25	STW	46	0.1	2.4	8.3	26	28
	26	STW	46	0.08	2.9	8.3	25	34
	27	STW	46	0.8	6.5	8.5	39	28
	28	STW	-	0.3	3.5	8.4	32	27
Tamta	29	STW	50	0.55	2.7	7.1	54	30
	30	DTW	900	0.01	4.8	7.4	19	28
West Kashimnagar	31	STW	36	0.65	3.0	8.2	17	31
	32	STW	-	0.9	4.0	7.5	16	29

	33	STW	46	0.4	2.9	7.9	30	30
	34	DTW	-	0.01	3.2	7.4	18	35
Rasulpur	35	STW	45	0.08	4.1	7.3	19	32
	36	STW	36	0.8	3.3	7.7	21	30
	37	STW	-	0.8	2.8	8.3	23	28
Panpara	38	STW	-	0.85	5.3	7.8	17	29
	39	STW	26	0.25	2.8	7.5	19	32
Fatehpur	40	STW	77	0.2	3.2	7.8	16	33
	41	STW	60	0.15	2.9	7.6	18	30
Chandpur	42	STW	35	0.15	-	7.7	16	29
	43	STW	65	0.35	4.7	7.4	12	28
Green Coconut water	44 (Augankhil)	-	-	0.001	3.00	7.7	0	0

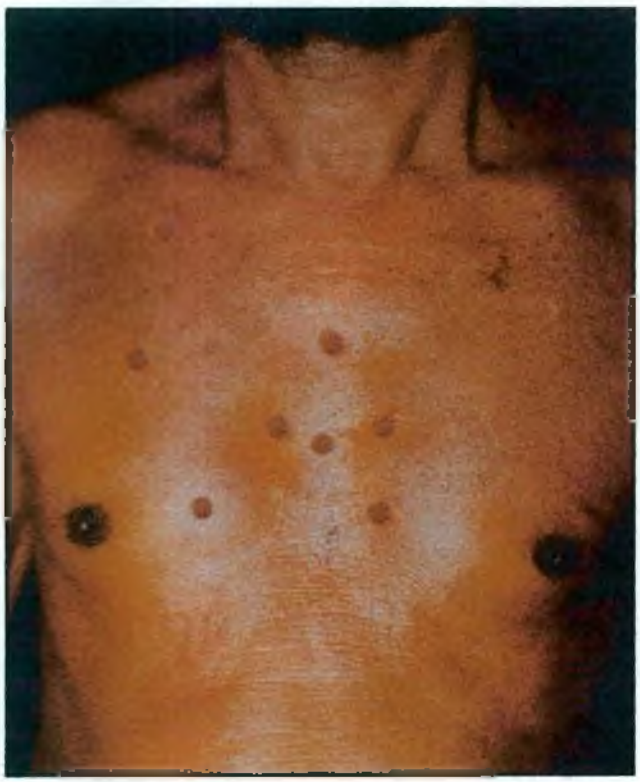
Appendix- E: Photograph



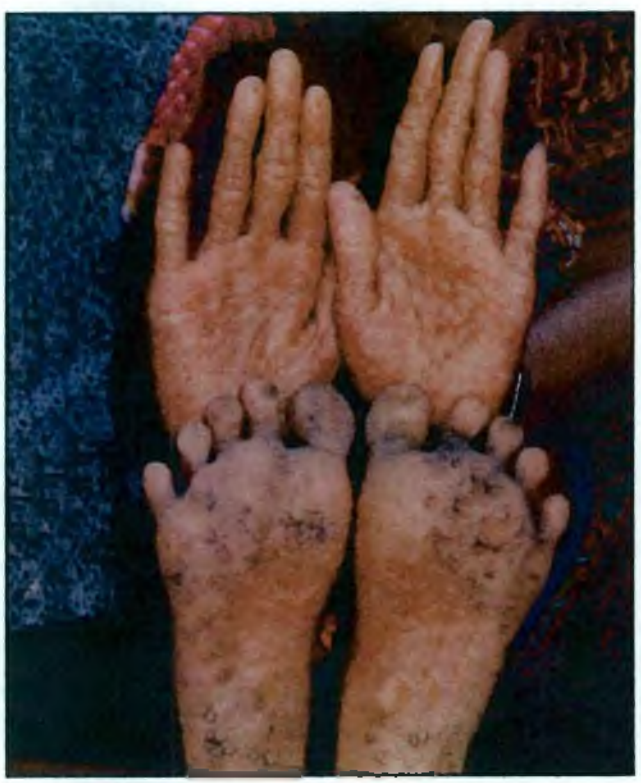
Photograph-1: Keratotis and Melanosis



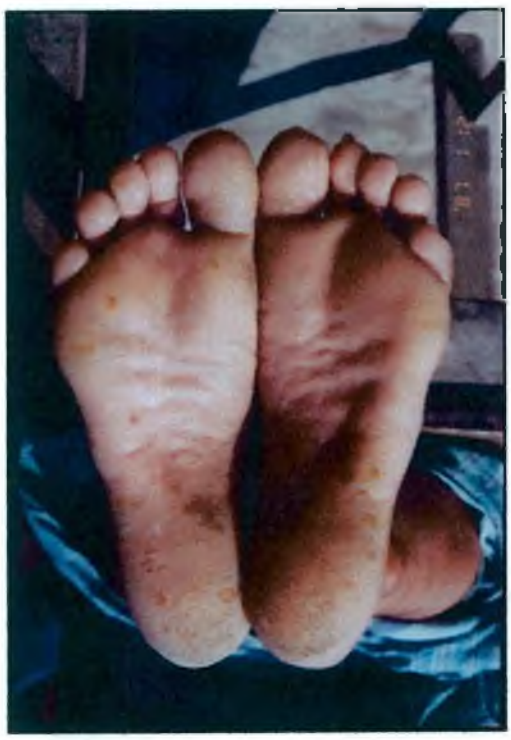
Photograph-2: Keratotis with Gangrene



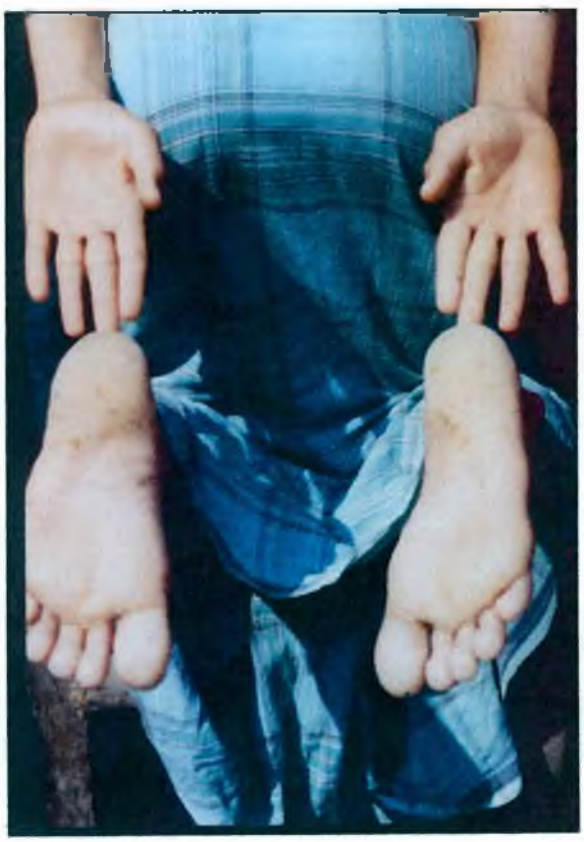
Photograph-3: Melanosis and Lecu melanosis



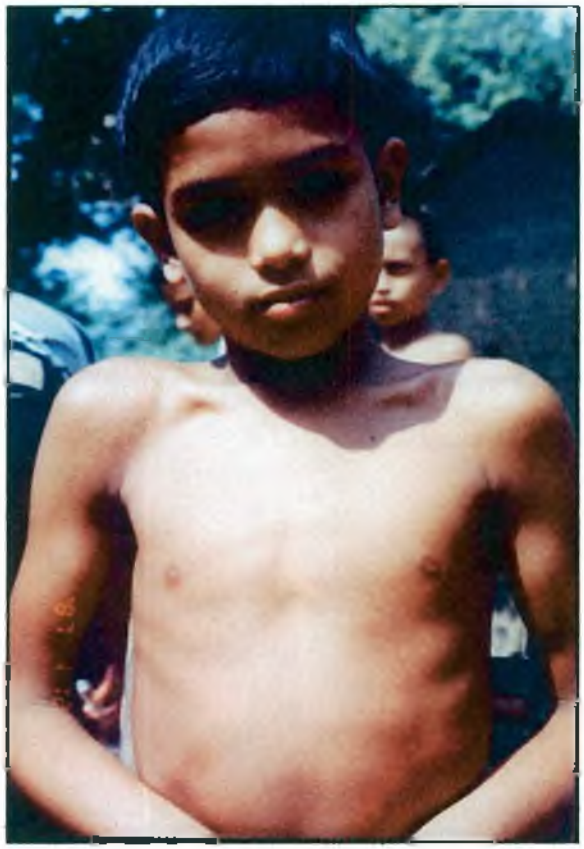
Photograph-4: Karatotis



Photograph-5: Keratotis



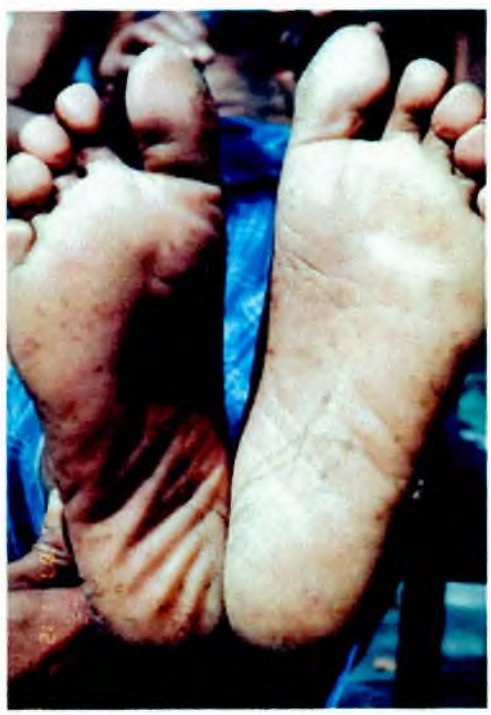
Photograph-6: Keratotis and Melanosis



Photograph-7: Melanosis

Photograph-8: Keratotis, Melanosis and Lecu Melanosis

Photograph-9: Keratotis and Melanosis



Photograph-10: Karatotis

Photograph-11: Deep Drilling Point

Photograph-12: Deep Drilling Working

Photograph-13: Field Kit Test of Aresenic,
Mr. M. K. Alam, Zakir, Shawzib (From Right to left)