VIABILITY OF ALTERNATIVE WATER SUPPLY TECHNOLOGIES FOR DRINKING PURPOSES AT A SEVERELY ARSENIC AND SALINITY AFFECTED AREA

Nargis Akter

Department of Civil Engineering

Bangladesh University of Engineering and Technology (BUET)

Dhaka

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by

Nargis Akter

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The thesis titled **"Viability of Alternative Water Supply Technologies for Drinking Purposes at a Severely Arsenic and Salinity Affected Area"** submitted by Nargis Akter, Roll No. **100604152P**, Session- October, 2006, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering (Environmental) on 14th March, 2015.

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Department of Civil Engineering,	
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Dr. Md. Niamul Bari	Member
Professor	(external)
Department of Civil Engineering	
Rajshahi University of Engineering and Technology (RUET), Rajshahi	

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Nargis Akter
Roll No. **100604152P**
Session: October, 2006

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LIST OF ABBREVIATIONS AND ACRONYMS

BBS	Bangladesh Bureau of Statistics
CBO	Community Based Organization
DART	Deployment of arsenic Removal Technologies
DCH	Dhaka Community Hospital
DFID	Department for International Development
DPHE	Department of Public Health Engineering
DTW	Deep Tubewell
ETV-AM	Environmental Technologies Verification – Arsenic Mitigation
EWAG	Swiss Federal Institute of Aquatic Science and Technology
GIS	Geographic Information System
GoB	Government of Bangladesh
HHs	Households
ICDDR'B	International Centre for Diarrhoeal Disease Research, Bangladesh
INGO	International Non-Government Organization
JICA	Japan International Cooperation Agency
LGIs	Local Government Institutions
MAR	Managed Aquifer Recharge
MDG	Millennium Development Goals
NGO	Non-Government Organization
PRA	Participatory Rural Appraisal
PWSS	Piped Water Supply System
RWHs	Rainwater Harvesting systems
STW	Shallow Tubewell
SWC	Safe Water Coverage
SWP	Solar Water Purifier
TDS	Total Dissolve Solids
TTC	Thermo Tolerent Coliform
UNICEF	United Nations Children's Fund
UP	Union Parishad
WASH	Water, Sanitation and Hygiene

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ABSTRACT

Detection of Arsenic in 1993, posed a great threat to ground water based rural water supply in Bangladesh. The national screening revealed that 29% hand pump tubewells were contaminated with arsenic more than Bangladesh Standards of 50 ppb. Comilla is one of the highest arsenic contaminated districts in Bangladesh. In addition, pockets of salinity have also been found within Comilla district. The study area Manohorganj Upazila under Comilla district is one of the most vulnerable upazila in context of arsenic and salinity.

Through this study the scale of water quality problem has been identified through random water sampling in shallow and deep aquifer, hydro- stratigraphy of the area has been analyzed through borelog analysis and performance of existing safe water technologies has been analyzed through socio –economic survey. The data of 754 GPS location has been collected for plotting GIS maps on water quality and safe water coverage which could be used for future reference. Union wise safe water technologies has been recommended based on the technical, social and economic findings from the study.

From Water Quality analysis it has been found that shallow aquifer of the 100% upazila is severely arsenic contaminated with concentration more than 300 ppb. Deep aquifer is found arsenic safe. But iron and manganese content exceeding more than Bangladesh standards are found all over the upazila. From the combined water quality map it has been found that almost 46% of the study area are vulnerable to iron (> 1.0 mg/L), manganese (>0.4 mg/L) and chloride (> 600 mg/L) in deep aquifer.

From hydrostratigraphy of the area and aquifer model it has been found that two distinct deep aquifer are present in the southern to central portion of the study area whereas in the northern portion, there is no 2nd deep aquifer up to the depth of 800 feet. Again in the eastern to central portion of the study area have two deep aquifer whereas in the western part there is one deep aquifer upto the depth of 800 feet.

Slurry conductivity test during the drilling of deep tube wells successfully identified the fresh aquifer in each union. It has been found that layers with slurry conductivity value less than 60 μS/cm mostly provided water with EC value less than 1500 μS/cm.

Variations were observed in static water tables in Shallow and Deep wells. In STWs water levels are still in suction limit whereas in DTWs the water levels are mostly beyond suction limit.

From data of safe water coverage, still 68.4% population are in dare need of arsenic safe water in the study area. The highest coverage union is Hasnabad (54% coverage) and the least covered union is Natherpetua (11% coverage). GIS based Union wise safe water coverage map has been produced for future reference.

From household survey and focus group discussion on existing technology performance, it has been found that Deep Tubewell (suction mode) and multiple connection are the preferred technology among others. Next preference is Piped Water Supply System (PWSS). Rainwater Harvesting System become the 3rd or 4th choice of people and last choice but not the least is other arsenic removal and treatment units.

Considering the hydrogeological context, hydro stratigraphy of the aquifer, site observation, water quality and water table situation and people's opinion a number of technologies has been recommended for future planning and interventions at union level.

Thus the study will contribute to making effective investments on safe and sustainable water supply for the 244,943 people of Manohorganj, wherein 4,172 arsenicosis patients will be benefitted from arsenic safe water and reduced health risk.

CHAPTER 1 : INTRODUCTION

1.1 Background

Bangladesh groundwater is plentiful and easily accessible at shallow depths. It is also of much better microbiological quality than the surface water sources which were traditionally used for drinking and other domestic purposes. By the early nineties, more than 90% of the rural population had access to presumably clean ground water. The discovery of arsenic in 1993 put a dent into this success story (Rosenboom et al., 2004). Exposure to arsenic through drinking water sourced from groundwater is a serious public health problem that is particularly devastating in Bangladesh (Ravenscroft et al., 2009; Smith et al., 2000). Arsenic is released from sediment by biogeochemical processes that promote reducing environments (Zheng et al., 2004; Nickson et al., 1998). According to survey data 2009, 97.8% of the population used an improved source of drinking water, but after adjusting for arsenic contamination this became only 85.5%. The survey found that 22 million people were still drinking water with arsenic concentrations higher than the Bangladesh standard of 50 μg/L (MICS, 2009).

Chronic arsenic exposure is linked to a range of dose-dependent conditions, including cancers of the skin, bladder, kidney and lung (Smith et al., 1998; Chen et al., 1992) as well as skin lesions. In Bangladesh, the risk of dying from ingestion of arsenic in drinking water has been shown to depend on the level of arsenic exposure (Argos et al., 2010; Sohel et al., 2009). Children are particularly vulnerable to arsenic poisoning than adults (GoB and UNICEF, 2010).

In Bangladesh context, groundwater has long been considered as the largest available source of fresh water because generally it is free from pathogenic micro-organisms and an efficient tool to prevent water borne diseases (particularly diarrhoeal diseases). Almost all rural water supplies and most of urban water supplies are groundwater based. About 80% of the total population of Bangladesh depends on shallow tube wells for drinking water. Now, this groundwater based water supply is a major concern to public health and socio-economic development of Bangladesh due to Arsenic (As) contamination in the shallow aquifers.

Since arsenic was first detected in 1993, Bangladesh has been ranked as the most vulnerable country in terms of population exposed to arsenic levels above the acceptable limit. Various programs have been undertaken to mitigate the arsenic contamination in Bangladesh. Despite various efforts, it is anticipated a considerable number of people are still exposed to high arsenic in drinking water. Various alternative water supplies and arsenic removal technologies have been endorsed in the National Policy for Arsenic Mitigation (2004) for use in arsenic affected areas; however, there have been operational challenges with most technologies, and sustainability is uncertain. Based on these technical challenges and the scale of the arsenic contamination, arsenic mitigation has been neglected in some areas like Comilla, where the mitigation is very challenging.

Bangladesh is facing another environmental and health threat due to man-made and natural factors: increased salinity. Salinity of drinking water is likely to have a range of health effects, including increased hypertension rates. Estimates indicate that Bangladesh has about 2·8 million hectares of land that is affected by salinity (Khan et al., 2008). Saline intrusion from sea water owing to reduction of freshwater flow from upstream (partly owing to the establishment of the Farrakka Barrage on the Ganges near the border of Bangladesh) is expected to be aggravated by climate change and sea-level rises. It has already had adverse effects on crop productivity and grain production. Now it appears to be a threat to the wellbeing of communities who live in coastal areas of this low-lying nation. In addition to coastal areas, some pocket areas of Bangladesh are also affected with salinity, such as Comilla district. Pockets of salinity have been found in Comilla district are rendering several deep tube wells unusable (Sara et al., 2011; Hoque et al., 2001).

There are many methods of salinity and arsenic mitigation that have been proved successful and are often deployed by government or non-governmental organisations (NGOs) in these countries. However, a standard monitoring method that evaluates the effectiveness of new schemes has failed to materialize due to a lack of baseline data, insufficient allocation of resources and proper operation and maintenance.

A cost effective survey approach is needed on a large scale and a small scale - firstly to determine the extent to which alleviation methods are working and secondly to identify individual schemes that are not functioning as they should. This approach needs to go beyond simply measuring arsenic and saline concentrations at project-provided water sources to understand if and for what purposes these are being used by the populations they are intended to serve, alongside other contaminated sources which may still be being used for cooking, washing or irrigating for rice production.

A comprehensive approach to arsenic and saline mitigation is required to address this crisis and to provide equitable access to all members in a community, including the most vulnerable.

In the Bangladesh context, arsenic and salinity are major concerns in providing safe drinking water and Manohorganj upazila under Comilla district exemplifies these issues. Therefore, it has been considered as the study area.

Thus, this study was intended to understand the hydrogeological and hydrochemical characteristics of the area focusing on arsenic and salinity, available safe water supply technologies and their performance and acceptance at community level, through which technologies could be ranked for future reference in effective water supply programme.

1.2 Rationale of the Study

Global reviews consistently show that WASH interventions are highly cost effective. The economic impact of poor sanitation and hygiene in Bangladesh has been calculated at four billion USD per year, or 6.3% of the GDP in 2007 (WSP & ADB, 2012). 85% of this burden derives from health-related impacts, especially premature deaths. A conservative estimate of economic impacts of arsenic-attributable mortality over the next 20 years is at least 6 – 20 billion USD, whereas the cost to provide arsenic safe water is 10 to 50 times less depending on the technology options used (Sara et al., 2012). In addition to the economic burden derived from lost work output, it is well known that chronic arsenic exposure is linked to a range of dose-dependent diseases including various cancers of the skin, bladder, kidney, and lung which can have a latency period of several decades, as well as skin lesions, hypertension and cardiovascular disease, pulmonary disease, peripheral vascular disease, diabetes mellitus, and neurological effects. Because the health effects are delayed the incidence of arsenic related diseases and mortality in Bangladesh can reasonably be expected to increase in the future as a result of past and continuing exposure to arsenic in this population. Thus, identifying the severity of arsenic and other water quality problems and assess the technologies to promote safe and sustainable water supply is urgent requirement.

To provide safe and sustainable water supply technologies is a big challenge in Manohorganj Upazila under Comilla district due to arsenic, salinity and other water quality problems. It is physically remote, and hydro- geologically challenging area where 98.8% STWs (DPHE & JICA, 2010) are arsenic contaminated. Existing water supply technologies provided by GoB/NGOs are not equally efficient considering socio-economic, climatological and hydro geological contexts of the area. Moreover, there is no/lack of information on hydro- geological and hydro- chemical characteristics of the area. Thus it is very much important to generate data on hydro –geological and hydro-chemical aspects, suitability of different technologies and also to assess the performance and acceptability of existing water supply technologies at community and house hold levels.

Furthermore, there is an urgent need of mapping of water quality problem areas and existing safe water technologies in the area to help the policy makers in future planning and interventions.

1.3 Specific Objectives

The specific objectives of the study are:

i. To identify the severity of arsenic and other water quality problems in Manohorganj;
ii. To assess the performance and acceptability of existing water supply technologies at community and house hold level;
iii. To mapping of water quality and existing safe water technologies in the area;
iv. To recommend the most appropriate water supply technologies for Manohorganj, considering its socio-economic, climatological and hydro geological context;

Thus the study will contribute to making effective investments on safe and sustainable water supply for the 244,943 people of Manohorganj, wherein 4,172 arsenicosis patients (DPHE & JICA, 2010) will be benefitted from arsenic safe water and reduced health risk.

1.4 Purpose and scope of the study

This study will try to identify the overall water quality problems and the best possible solution for safe water supply considering hydrogeological, technical, socio- economical point of view. The scope of work to achieve these objectives are:

- Data collection from field and from different organizations
- Water quality testing at field
- Water quality testing at BUET Lab
- Questionnaire survey at household level
- GIS mapping
- Data analysis and reporting

1.5 Ethical consideration

The study was implemented in the field by ensuring the protection of rights of the respondents, prior to approaching them for the data collection, water sample collection and detailed interview, their oral consent was obtained. They were provided with full and correct information regarding the purpose of the data collection, benefits of the study, confidentiality to be maintained and freedom to be exercised by the respondents during the interviews. Furthermore the interviewers responded to questions and provided necessary clarifications asked by the respondents. The interview was held under conditions wherein the respondents were quite comfortable in responding.

1.6 Study limitation

The limitation of the study was mainly to select the household across the study areas. The households were selected from underprivileged people of the community, this may change in future. Moreover, every effort was made to visit the randomly selected sample of the communities; it was not always possible to visit most of the remote areas by the data collectors. As a result, actual socio-economic condition of the studied communities may vary from the findings outlined in the household demographics.

1.7 Organization of the report

This study devised and carried out a huge water quality survey and a questionnaire survey of arsenic and saline affected peolple in 11 unions of Manohorganj upazila during 2012 and 2013 with support from local people. After further explanation of the background, rationale and objectives in Chapter 1, a summary of literature survey on the context of arsenic exposure, pathways and the discovery of the enormous scale of the problem in the Bengal Basin, effect and mitigation interventions had given in Chapter 2.

Chapter 3 discussed the methodology of the study and Chapter 4 describes the study area, its profile, hydrogeology and drinking water supply status. It also describes the existing different alternative safe water technologies and arsenic removal technologies with detail information of functionality, merits, demerits, costs and O&M.

Chapter 5 is the study results and discussion. It describes the scale of water quality problem in shallow and deep aquifer and mapping of the problem, aquifer characteristics, the comparative assessment of the technical, social and economic aspects of each of the existing technologies, rank of existing technologies.

Chapter 6 focuses on the final outcome of the study the conclusions and recommendations of possible future technologies for this upazila.

Annexes include the borelog data, water quality data, questionnaires prepared for the technology assessments, union wise safe water mapping, etc.

CHAPTER 2 : LITERATURE REVIEW

Arsenic is a global public health concern as it has been detected in groundwater of many countries where this is used as a main source of drinking water. Our knowledge about arsenic occurrence and distribution in groundwater and their impacts on public health improved significantly over the last few years as a result of large number of researches conducted in various parts of the globe. A large number of researches have been carried out in Bangladesh alone covering all aspects of the arsenic in groundwater. Also a number of studies carried out in saline areas. Major publications in the fields of hydrogeological, technological, agricultural, water supply aspects on arsenic and salinity issue have been reviewed as part of literature review which is presented in the following section.

2.1 Arsenic in Groundwater

2.1.1 Occurrence and Distribution

Arsenic concentrations greater than 50 µg /Liter was first reported from the Bengal Basin in 1978 in West Bengal (Acharyya et al., 2000) and the first cases of arsenic poisoning were diagnosed there in 1983 and dermatologist K.C. Saha identified these early cases of arsenic- induced skin lesions in Kolkata, India (Smith et al., 2000). Though earlier patients were from West Bengal, by 1987 several patients had been identified in India who came from neighbouring Bangladesh (Smith et al., 2000). The contamination of groundwater by arsenic in Bangladesh was first confirmed by the DPHE in Chapai Nawabganj in late 1993 following reports of extensive contamination in the adjoining area of West Bengal.

The issue of arsenic contamination in West Bengal achieved international recognition in 1995 when the SOES at Jadavpur University, Calcutta hosted an international conference on the subject. Arsenic-affected patients from both West Bengal and Bangladesh were presented to participants. Since the mid-1990s, SOES in conjunction with DCH have conducted field investigations in various parts of Bangladesh including a large number of water analyses and tissue analyses.

Since first detection in 1993, a large number of local, regional and national investigations have been conducted in the country. More than half of the countries over 10 million wells have been tested mostly using field kits. Relatively smaller numbers of wells have been tested using laboratory techniques.

2.1.2 Arsenic Origin and Release Mechanisms

Mobilisation of arsenic into the groundwater is controlled by redox reactions in the aquifers and hence concentrations of redox sensitive parameters viz. Eh, HCO_3^- DOC, SO_4^{2-}, NO_3^-, NH_4^+, Fe and Mn in the groundwater are important in understanding the redox conditions (Nickson *et al.,* 2000; Zheng et al., 2004). It has been postulated that the degradation of natural organic matter by micro-organisms in the Holocene alluvial aquifers of the Ganges Brahmaputra Meghna delta is responsible for causing reducing conditions in the aquifers and generation of high HCO_3^- and DOC in the groundwater (McArthur *et al.,* 2001). The relationships of Eh, As, HCO_3^- and DOC in the Holocene and Pleistocene aquifers along the transect thus reflect the variability of redox conditions with the change in geology and associated biogeochemical processes. Microbially mediated reductive dissolution of metal (Fe, Mn, Al)-oxyhydroxides containing arsenic in presence of organic matter is the most widely accepted hypothesis as the principal mechanism for elevated level of arsenic in the shallow alluvial aquifers in the Bengal Basin (Nickson *et al.,* 1998).

Recent investigations in Bangladesh and other countries put new light on origin and release mechanism of arsenic. There is more evidence about the natural geochemical process, i.e. microbially-mediated reductive-dissolution of iron oxyhydroxide by organic carbon. However, there have been debates about the origin of the organic carbon, whether it is predominantly sedimentary or derived from ponds and paddy fields. Studies from Bangladesh and West Bengal have reached opposite conclusions. The roles of geomorphology, hydrology and subsurface sediment characteristics conducive to arsenic occurrences are better understood.

2.2 Arsenic in Environment

Arsenic in Soil

Inorganic arsenic occurs naturally in soil and in many kinds of rock, especially in minerals and ores that contain copper or lead. A detailed consideration of arsenic in irrigated soils is beyond the present scope. The background level of arsenic in non-irrigated soils in Bangladesh is around 5-10 mg/kg. However, in irrigated soils concentrations are regularly several tens of mg/kg (Meharg and Rahman, 2003) have demonstrated a halving of rice yield at soil concentrations of around 50 mg/kg. Further, many others, have demonstrated significant uptake of arsenic into rice in irrigated regions, including in non-irrigated crops in those regions.

Arsenic in Irrigation Wells

No systematic national survey, like the ones for drinking water, of arsenic in irrigation wells has so far been conducted in the country. However, there has been testing of arsenic in irrigation wells conducted under various project and studies such as the NMIDP, BADC, BMDA and USAID etc. All the available results have been combined to assess the extent of arsenic in irrigation wells on a national scale. The total area under irrigation in Bangladesh is 5,049,785ha and 78.9% of the area is covered by groundwater sources including 3,197,184ha with 1,304,973 STWs and 785,680ha with 31,302 deep tubewells DTWs as reported by BADC (2007).

No systematic National survey has so far been conducted the assessment of the arsenic contamination scenario in irrigation wells. First survey of irrigation wells arsenic was carried out in the North East Minor Irrigation Project area in late nineties where samples from a good number of wells were analysed at BUET and BCSIR laboratories. Subsequently, BADC tested about 10,000 wells from different parts of the country (BADC, 2007). Also BMDA analysed about five thousand wells from northwest region of the country. Out of 14,806 irrigation wells, 21% exceed the drinking water safe limit of 50 ppb and 12% exceed the 100 ppb limit. However, majority of the wells are below the 10 ppb limit (63%). testing have been assembled for this review.

Arsenic in Rice

It has been reported by a number of studies that significant amount of arsenic can be ingested through food, mainly rice. However, the concentrations taken by rice depend on number of factors including concentrations of arsenic in irrigation water. Also total intake depends on issues like cooking practices and amount of rice taken. Arsenic build up in soil has also been mapped and yield reduction of paddy has been reported (Meharg and Rahman, 2003).

2.3 Salinity in Groundwater

Salinity in Groundwater is a critical issue at present time. Salinity means the presence of major dissolved inorganic solutes (essentially Na+, K+, mg+, Ca+, Cl-, NO3-, SO4 2-, HCO3-, CO3 2-) in aqueous solution. The presence of soluble salts in the groundwater and surface water bodies as well as in the soil is one of the major environmental problems worldwide. Salinity causes many economic and environmental costs. These include reduction in agricultural productivity, decline in the quality of water supplies for drinking, irrigation and industrial use, loss of biodiversity in both terrestrial and aquatic ecosystems, and also damage to urban infrastructure (Afroj, 2011).

Increasing salinity is one of the most significant environmental problems posing around the world. Water is a critical issue for the survival of all living organisms. Some can use salt water but many organisms including the great majority of higher plants and most mammals must have access to fresh water to live.

Fresh water can be defined as water with less than 500 parts per million (ppm) of dissolved salts.

Water salinity based on dissolved salts			
Fresh water	Brackish water	Saline water	Brine
< 0.05%	0.05–3%	3–5%	> 5%

There are many causes of the apparent decrease in our fresh water supply. Principal amongst these is the increase in population through increasing life expectancy, the increase in per capita water use and the desire of many people to live in warm climates that have naturally low levels of fresh water resources. Climate change is also likely to change the availability and distribution of fresh water across the planet:

"If global warming continues to melt glaciers in the polar regions, as expected, the supply of fresh water may actually decrease. First, fresh water from the melting glaciers will mingle with salt water in the oceans and become too salty to drink. Second, the increased ocean volume will cause sea levels to rise, contaminating freshwater sources along coastal regions with seawater" (Wikipedia, fresh water).

2.4 Statement and scale of the problems

2.4.1 Global Context

A) Global Context - Arsenic Contamination

Arsenic pollution has been reported from more than 70 countries on six continents, and the picture is still incomplete, with no information from large parts of the globe. The concentration of arsenic in natural waters, including groundwater, is typically below the WHO provisional guideline value for arsenic in drinking water of 10 µg/li. However, arsenic mobilization in water is favored under some specific geochemical and hydrogeological conditions and concentrations can reach two orders of magnitude higher than this in the worst cases. Most of the extensive occurrences of high-arsenic groundwater are undoubtedly of natural origin, that is to say they involve the mobilization of arsenic naturally present in the ground and not the discharge of pollutants at the land surface, although the extent to which mobilization can be accelerated by groundwater pumping is still open to question.

Figure 2.1 shows the distribution of documented cases of arsenic contamination in groundwater and the environment worldwide. Many of these cases are related to areas of mineralization and mining activity and a few are associated with geothermal sources. While these cases can be severe, with high concentrations of arsenic in waters, sediments, and soils, their lateral scale is usually limited. Other areas with recognized high-arsenic groundwater are not associated with obvious mineralization and mining or geothermal activity. Some of these occur in major aquifers and may be potentially much more serious because they occupy large areas and can provide drinking water to large populations (Kemper et al., 2004).

Figure 2-1: Distribution of Arsenic in Groundwater and Environment in the World

Major alluvial plains, deltas and some inland basins composed of young sediments are particularly prone to developing groundwater arsenic problems. Several of these aquifers around the world have now been identified as having unacceptably high concentrations of arsenic. These include not only the alluvial and deltaic aquifers in parts of Asia, but also inland basins in Argentina, Chile, Mexico, the southwestern United States, Hungary, and Romania. Important differences exist between these regions, but some similarities are also apparent. The majority of the high- arsenic groundwater provinces are in young unconsolidated sediments, usually of Quaternary age, and often of Holocene deposition of less than 12,000 years in age. These aquifers do not appear to contain abnormally high concentrations of arsenic-bearing minerals but do have geochemical and hydrogeological conditions favoring mobilization of arsenic and its retention in solution.

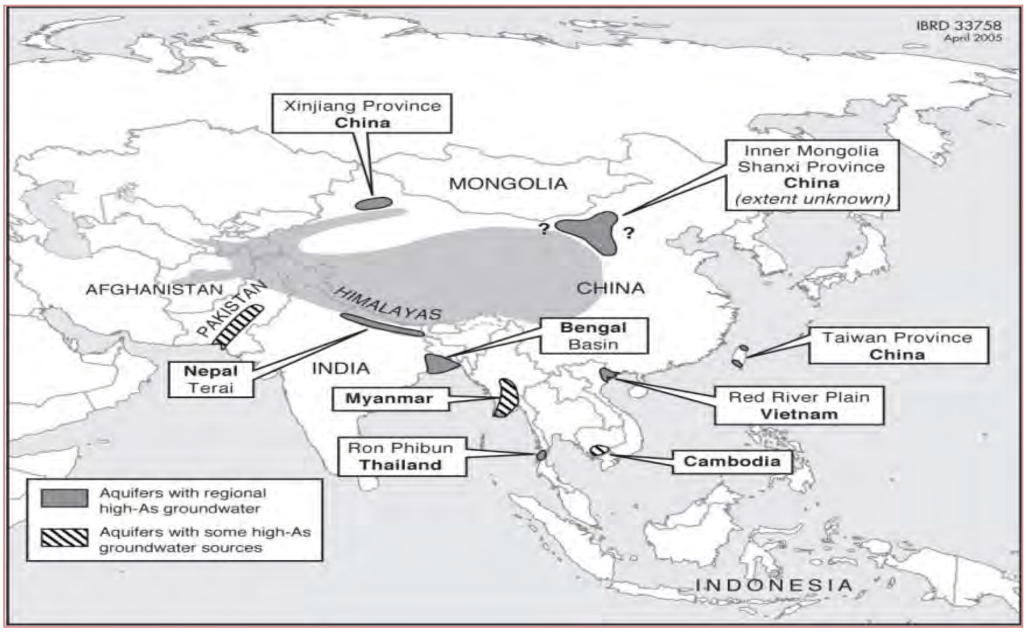


Figure 2-2: High-Arsenic Groundwater Provinces in South and East Asia

Many of the world's aquifers with high arsenic levels are located in those areas of Asia where large alluvial and deltaic plains occur, particularly around the perimeter of the Himalayan mountain range. In South Asia, naturally occurring arsenic in groundwater was initially identified in West Bengal, India, and in Bangladesh in the early 1980s and 1990s respectively. Since then governments, donors, international organizations, NGOs, and research institutions have increased testing of groundwater sources. As a result, naturally occurring arsenic has now been identified in the groundwater of the countries in South and East Asia.

Figure 2.2 shows the locations of high-arsenic groundwater provinces in the countries of South and East Asia. There may be other Quaternary aquifers with high groundwater arsenic concentrations that have not yet been identified, but since awareness of the arsenic problem has grown substantially over the last few years, these are likely to be on a smaller scale than those already identified.

Many of the health consequences resulting from contaminated groundwater have emerged in relatively recent years as a result of the increased use of groundwater from tubewells for drinking and irrigation. In terms of numbers of groundwater sources affected and populations at risk problems are greatest in Bangladesh, but have also been identified in

India (West Bengal, and more recently Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Tripura and Uttar Pradesh), China, including Taiwan, Vietnam, Thailand, Cambodia, Myanmar, and Nepal. Occasional high-arsenic groundwaters have also been found in Pakistan, although the occurrences there appear to be less widespread. Hence, much of the distribution is linked to the occurrence of young (Quaternary) sediments in the region's large alluvial and deltaic plains (Bengal basin, Irrawaddy delta, Mekong valley, Red River delta, Indus plain, Yellow River plain).

Bangladesh is most vulnerable to groundwater Arsenic contamination among South and East Asian countries in term of population at risk and areal extent. At present, Arsenic is present in drinking water in 61 out of 64 districts of Bangladesh. In Bangladesh, 4.95 million tubewells have been screened where 3.50 million (71%) gets green (As contamination less than the nation acceptable limit 50 µg/L) and 1.44 million (29%) gets red (As contamination higher than the nation acceptable limit 50 µg/L) (Nickson, et al., 1998).

Arsenic concentration is higher in shallow aquifers than deep in Bangladesh. Quaternary, largely Holocene, alluvial and deltaic sediments from Ganges-Brahmaputra-Meghna river system are the Arsenic affected aquifers in Bangladesh and specially groundwater from the Holocene (<150m) aquifers contains arsenic contamination up to around 2,300 µg/L (Smith et al., 2000).

B) <u>Global Context – Saline Contamination</u>

Out of all the water on Earth, salt water in oceans, seas and saline groundwater make up about 97% of it. Only 2.5–2.75% is fresh water, including 1.75–2% frozen in glaciers, ice and snow, 0.7–0.8% as fresh groundwater and soil moisture, and less than 0.01% of it as surface water in lakes, swamps and rivers. Freshwater lakes contain about 87% of this fresh surface water, including 29% in the African Great Lakes, 20% in Lake Baikal in Russia, 21% in the North American Great Lakes, and 14% in other lakes. Swamps have most of the balance with only a small amount in rivers, most notably the Amazon River. The atmosphere contains 0.04% water. In areas with no fresh water on the ground surface, fresh water derived from precipitation may, because of its lower density, overlie saline ground water in lenses or layers. Most of the world's fresh water is frozen in ice sheets. Many areas suffer from lack of distribution of fresh water, such as deserts (Wikipedia, Fresh water).

The World Bank adds that the response by freshwater ecosystems to a changing climate can be described in terms of three interrelated components: water quality, water quantity or volume, and water timing. A change in one often leads to shifts in the others as well. Water pollution and subsequent eutrophication also reduces the availability of fresh water.

Also, there is an uneven distribution of fresh water. While some countries have an abundant supply of fresh water, others do not have as much. For example, Canada has 20% of the world's fresh water supply, while India has only 10% of the world's fresh water supply; what more India's population is more than 30 times larger than that of Canada. A reason for the uneven distribution of fresh water supply may be the differences in climate. For example, in some countries in Africa, the frequent lack of rain has led to insufficient water supply for irrigation. This has affected agriculture and has led to a shortage of food for the people (Wikipedia, Fresh water).

Many areas of the world are already experiencing stress on water availability. Due to the accelerated pace of population growth and an increase in the amount of water a single person uses, it is expected that this situation will continue to get worse. A shortage of water in the future would be detrimental to the human population as it would affect everything from sanitation, to overall health and the production of grain.

2.4.2 Bangladesh Context

A) Bangladesh Context - Arsenic Contamination

In Bangladesh the presence of arsenic in groundwater was first detected in 1993 at Barogharia union of Chapai Nawabganj district. Since the discovery of the arsenic problem in Bangladesh, significant work has been carried out to try and address the situation. This includes research, identification of the scale of the problem, awareness raising and attempts to provide alternatives to mitigate the problem (DPHE & JICA, 2010).

Naturally occurring arsenic in the Himalaya has been carried by the Ganges and Brahmaputra rivers to be released into groundwater in the densely populated delta, where it pollutes shallow wells that were previously thought to be the solution to epidemics of diarrhoeal disease. Arsenic in water cripples and kills, and stunts the intellectual development of children. It creates social havoc, especially for women, and ruins the economy through its debilitating effects on working people. Despite the money and effort that has been committed, attempts to solve this problem have lost momentum, and worse arsenic poisoning is becoming accepted as the inevitable fate of the Bangladeshi people. However, this is not inevitable; arsenic poisoning from drinking water can be stopped.

The first national survey in 1998-99 found that 27 million people were drinking water containing more than 50 µg/L of arsenic, the drinking water standard in Bangladesh, which is five times what is considered safe in Europe and America. By 2009, this had fallen to 22 million – progress, but not enough. If nothing is done, one in every hundred will die from cancers attributable to arsenic. A far larger number will suffer from serious and debilitating illnesses, including disfiguring and painful skin conditions. The added burden of arsenic poisoning has places a huge strain on a country already struggling to meet the basic needs of its citizens.

According to UNICEF, an area (usually a geographic unit such as district or village) in which at least 5% of tube-wells exceed the national standard is considered as Arsenic-affected. Following this principle, Table 2.1 shows (BAMWSP, 2006) that 47 districts, 233 Upazilas, 2,213 unions, and 31,497 villages can be considered “arsenic-affected”.

Table 2-1: Proportion of wells exceeding 50 µg/L standard at different scales

Proportion of wells >50 µg/L	**Districts**	**Upazilas**	**Unions**	**Villages**	**Population (million)**
<= 5%	7	35	668	22,544	22.3
>5-40%	31	145	1,176	14,788	20.8
>40%-80%	15	65	621	8,331	11.7
>80-100%	1	23	416	8,378	10.1
Total arsenic affected	47	233	2,213	31,497	
Total Screened	54	268	2,881	54,041	64.9
Total not Screened (likely unaffected)	10	204	1,603	33,278	75.1
Total in Country	64	472	4,484	87,319	140

The Table 2.1 also represents the village population by different risk categories. By multiplying the proportion of contaminated wells (more than 5%) at each village by the village population, it is estimated that 20.8 million people about 14% of the total national population are at risk of arsenic exposure. Figure 2.3 shows the effect of arsenic.

Figure 2-3: Effect of Arsenic

B) <u>Bangladesh Context – Saline Contamination</u>

Water circulation in the coastal zone and in the Meghna estuary in Bangladesh is largely dependent on the factors like fresh water flow from the river, penetration of tide from the Bay of Bengal and the meteorological conditions like low pressure systems, cyclones, and storms surge and wind. Both climatic and anthropogenic factors are responsible for causing salinity in the river water. However, climate induced factors such as sea level rise is the most pressing cause of salinity in coastal areas (Afroj, 2011).

For the deposition of silt and clay, the spatial distribution and concentrations of salinity in the estuary are important in the formation of the delta. The intrusion of saline water inland determines the suitability of estuary water for drinking, irrigation and other purposes. During the wet season, the vertical variation of salinity may play a role in the seasonal storage of sediment at the outside of the estuary. Because of its shallow depth, the Meghna Estuary is generally a well-mixed estuary where the salinity is constant in a vertical water column (BWDB et al., 1998). During the monsoon, the Land Reclamation Project (LRP) and Meghna Estuary Survey (MES) measured an approximately 100 km long zone (Kutubdia-Sandwip) that develops in the southeastern part of the estuary where vertical variation occurs when a layer of brackish water moves in with the tide in the form of a salt wedge. The general concept is that during the dry season, part of the sediment is brought back into the estuary through a so-called tidal pumping process, and deposited there (BWDB et al., 1998). In the coastal area of Bangladesh salinity increases during minimum river discharges but never exceeds seawater salinity (34 ppt). Intrusion of saline water during the dry season is up to Char Gazaria where salinities are less than 1 ppt. Salinity intrusion can increase either due to a decrease of fresh water flow in the Lower Meghna River during the dry season, or due to further penetration of tide into the river system. Intrusion may be aggravated by upstream withdrawal of water and the reducing size of floodplains, or by climate change impacts like a decrease in dry season rainfall and sea level rise.

A Doctoral thesis (Hasan, 2008) stated that high concentrations of arsenic and salinity are the major constraints for groundwater development in the Holocene alluvial aquifers of the Meghna basin. The Holocene shallow aquifers (<150 m) are high in dissolved arsenic and salinity, while the Holocene deeper aquifers (>150 m) are low in arsenic but contains pockets of saline groundwater. Molar ratios of Cl^-/HCO_3^- and Na^+/Cl^- indicate mixing of relict seawater with the freshly recharged water in these aquifers. Electrical conductivity varies over a wide range between 146-4990 µS/cm in the aquifers of the study area in north part of Comilla district. Occurrence of high EC (>1000 µS/cm) in groundwater is found both in shallow and deeper aquifer but restricted only in the western part. The spatial distribution pattern of EC for shallow aquifer (Fig. 2.4) indicates presence of pockets of saline groundwater in the western part. It has been hypothesized that origin of such groundwater is the result of mixing of fresh water with the ancient seawater trapped within the formation during Holocene sea level transgression. The Holocene sea level rise between 7000-5000 years before present (BP) has a great influence on the nature of sedimentation and groundwater quality in the Bengal Basin.

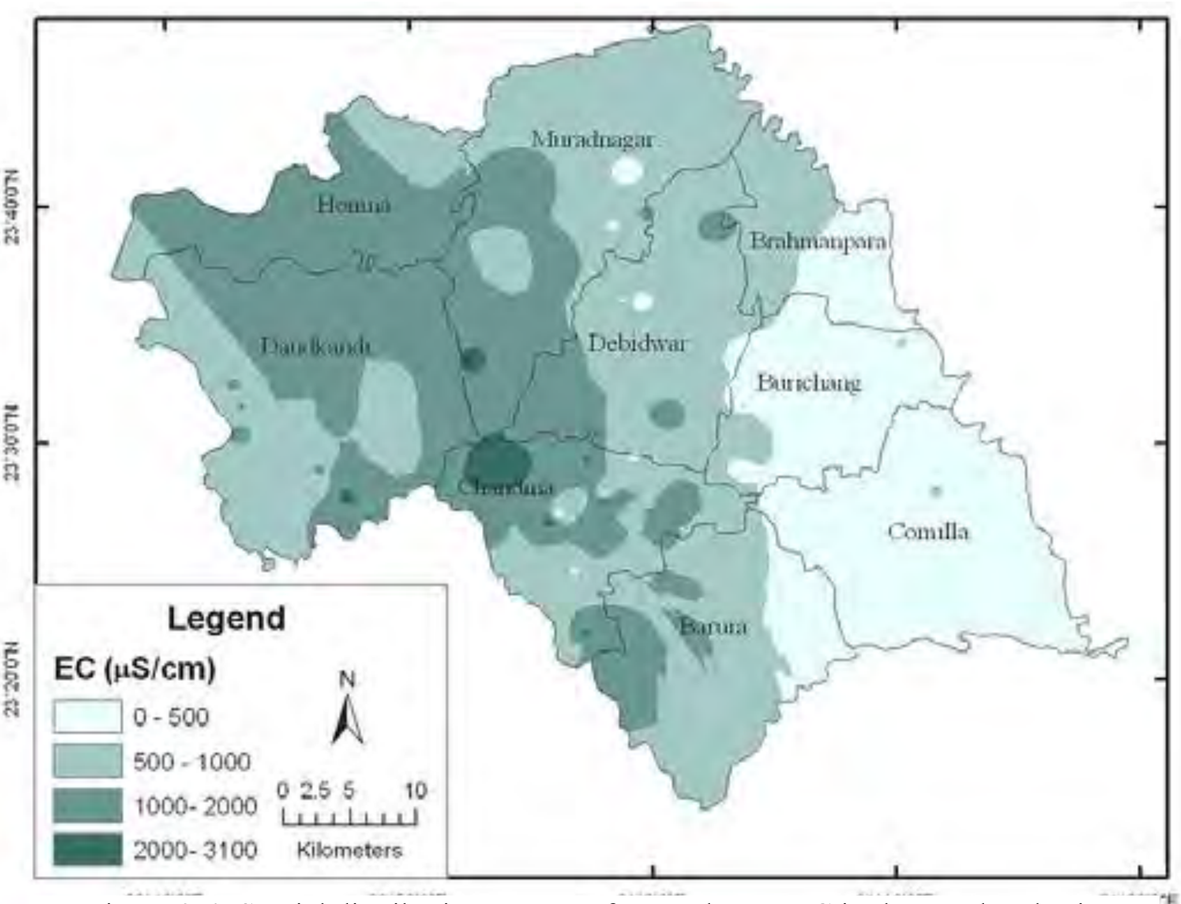


Figure 2-4: Spatial distribution pattern of groundwater EC in the Meghna basin

2.5 Arsenic Major Investigations

National Hydrochemical Survey (NHS), 1998-99

BGS conducted the Rapid Assessment Phase of the survey named as Groundwater Studies for Arsenic Contamination in Bangladesh with support from DPHE and BGS in 1999. The second phase of the survey was conducted by BGS with support from DPHE in 2001. The landmark survey was conducted in 1998-99 covering the most of the country except parts of Chittagong districts and the 3 hill districts. The survey for the first time produced the

National Map of arsenic distribution in groundwater. The survey reported that 29% of the sampled shallow hand tube wells exceeded the Bangladesh drinking water limit of 50 ppb and 2% of the deep hand tube wells exceeded the same limit. Apart from the National survey, investigations were carried out in three upazilas, Chapai Nawabganj Sadar, Faridpur Sadar and Lakshmipur Sadar, for understanding the release mechanism, geological controls, temporal distributions of arsenic, etc. The survey results demonstrated the control of surface geology on the occurrence of arsenic, i.e. arsenic found to occur only in the Holocene Plains, not in the Pleistocene terraces. The survey also reported that wells deeper than 150m were safe from arsenic. The survey results also confirmed the origin of arsenic from reductive dissolution. The main outcome of the survey was the spatial distribution of arsenic in Bangladesh groundwater. The results were subsequently used for designing the BAMWSP (DPHE & JICA, 2010).

BAMWSP National Screening Data

Bangladesh Water Supply Arsenic Mitigation Project (BAMWSP) was undertaken in 1999 to provide arsenic safe water in the affected regions of the country. The project was taken as a project of DPHE under the World Bank funding. One of the major achievements of the project was completion of screening of all water supply wells in rural areas of the arsenic affected upazilas of the country. BAMWSP, along with UNICEF, World Vision, DANIDA and AAN tested all wells in 270 Upazilas of the country during the period 2001 to 2003. The survey upazilas were selected based on the NHS conducted by DPHE/MMI/BGS in 1998-99. About 4,943,225 wells were tested using field test kits. The survey collected information of wells and identified patients with visible arsenicosis symptoms. However, the patient identification was not done proper medical personnel. The main outcome of the survey was the identification of villages where more than 80% wells exceeded the Bangladesh drinking water limit. These villages were subsequently included under the emergency mitigation plan (DPHE & JICA, 2010).

DPHE-UNICEF Screening in Non-affected Upazilas

BAMWSP national screening covered the 270 arsenic affected upazilas of the country. Another village level survey was undertaken by R&D Division of DPHE in 2002 under the joint initiatives of DPHE and UNICEF in 192 Upazilas of the country covering plain and hilly areas. Under the survey a total of 164,152 wells were tested of which only 4,822 (2.94%) exceeded the 50 ppb limit (Table 2-2). The percentage of contaminated wells varied from 0 to 35.7% in the surveyed upazilas.

Table 2-2: Arsenic concentration in drinking water and proportions exposed as determined by testing during national surveys, Bangladesh (DPHE & JICA, 2010)

`	**Total Wells**	**Number of Wells with As <50 ppb**	**% of wells with As <50 ppb**	**Number of Wells with As >50 ppb**	**% of wells with As >50 ppb**
BAMWSP (270)	4,943,225	3,502,816	71	1,440,409	29
DPHE/UNICEF (192)	164,152	159,330	97	4822	3
Total (462)	5,107,377	3,662,146	72	1,445,231	28

The survey also identified 14 upazilas with more than 10% wells exceeding the 50 ppb limit and recommended those upazilas for full screening.

Population Exposed

Exposure to arsenic through drinking water sourced from groundwater is a global public health problem that is particularly devastating in Bangladesh. Various numbers have been put forward by different authors/studies for the number of people exposed to arsenic in drinking water above 50 ppb in Bangladesh. According to survey data from 2000 to 2010, an estimated 35 to 77 million people in the country have been chronically exposed to arsenic in their drinking water (Sara et al, 2012).

Using Sohel et al.'s HR for non-accidental deaths, Sara et al., modelled excess deaths for all districts and arrived at an annual total of nearly 43 000 deaths, representing about 5.6% of all deaths, as being attributable to chronic arsenic exposure at current exposure levels. On the basis of Sohel's cause-specific mortality hazard ratios, about 1 in 16 cancer deaths, 1 in 36 cardiovascular disease deaths and 1 in 19 deaths from infections are attributable to arsenic exposure.

The 2009 Bangladesh Multiple Indicator Cluster Survey (MICS) included collection of drinking water for arsenic tests from 15000 randomized households nationwide. The National Drinking Water Quality Survey report used an estimated national population of 164 million to estimate that 22 million and 5.6 million people are drinking water with arsenic concentrations > 50 µg/L and > 200 µg/L, respectively. According to preliminary census figures for 2011, the population of Bangladesh is about 142.3 million. Based on this figure, the people drinking water having arsenic concentrations > 50 µg/L and > 200 µg/L are approximately 19 million and 5 million, respectively. These estimates can be revised upwards with the final 2011 census figures which is 20 million having arsenic concentrations 50 µg/L (Sara et al, 2012).

Mitigation Options

Various different mitigation options have been installed to provide arsenic-safe water in the areas where more than 50 ppb arsenic has been detected. APSU in 2005 conducted a national survey to identify the number of options installed by various government and non-government programs. A large number of agencies installed 106,939 safe water options in different parts of the country as shown in Table 2-3. The table include various options based on surface, rain and ground water. The relative contributions of the various options are shown in Figure 2-5. It is evident from the Figure that 70% of the mitigation is provided by DTW followed by 12.5% rain water. It is estimated that these options can provide water supply to 4,546,532 households or 38% of the total household in arsenic affected areas. It is very interesting note that majority of these options (more than 80%) were installed under regular water supply programs of DPHE/ UNICEF and DPHE/DANIDA (Position Paper, BUET, 2005).

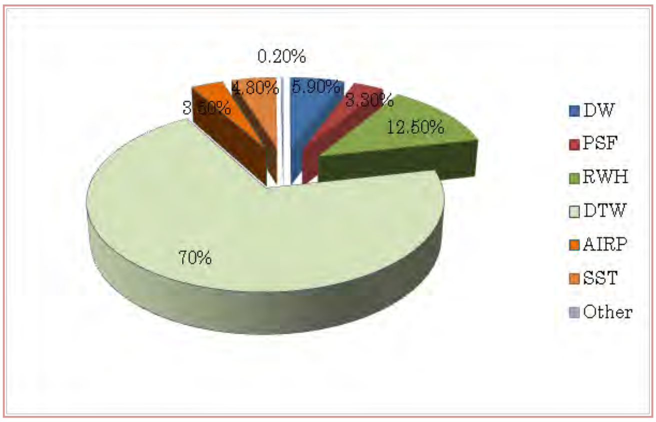


Figure 2-5: Proportion of various safe water options installed in arsenic affected areas

Table 2-3: Various safe water options installed by stakeholders

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

Ravenscroft et al (2009) compiled the number of safe water options installed for arsenic mitigation in Bangladesh. According to them, deep tube wells provide 84.4% followed by shallow tube wells (5.1%) and dug wells (4.9%). Therefore, groundwater account for more than 94% of safe water options followed by 3.2% by rainwater and 1.4% by surface water (PSF). Contribution of arsenic removal technologies is insignificant.

MICS Data on Arsenic in Household Water

Arsenic status in household water has been assessed under the recently conducted Multiple Indicator Cluster Survey (MICS) conducted by Bangladesh Bureau of Statistics and UNICEF (BBS/UNICEF, 2010). The survey covered the entire country. A glass of drinking water was collected from each Households covered under the survey which was tested for arsenic content. Water samples were collected from 15,000 households, of which 13,301 samples were tested (88.6%). Samples were analyzed in Bangladesh with a small portion was sent to Canada as part of the QC program.

Overall, 12.6% (6.2% per cent in urban and 14.0% in rural areas) of households drinking water arsenic exceeded the Bangladesh standard, while 23.1% (14.3% in urban and 25.1% in rural areas) exceeded the WHO's guideline. 3.3% (1.4% urban and 3.5% rural areas) of households with arsenic contamination higher than 200 ppb.

According to this survey, 85.2% of population is currently using an improved drinking water source (93.3% in urban and 83.4% in rural areas) following the Bangladesh national standards. However, using the WHO guideline, 74.7% of population is using an improved drinking water source in Bangladesh - 85.2% in urban and 72.3% in rural areas.

The district-wise pattern of people drinking relatively higher concentrations of arsenic is very similar to the spatial distribution depicted in earlier studies. However, relatively higher proportions have been found in few districts of Sylhet Division where arsenic surveys found relatively lower proportions of wells exceeding Bangladesh limit. Arsenic Contamination in Household Drinking Water has been shown in the map (Figure 2-6).

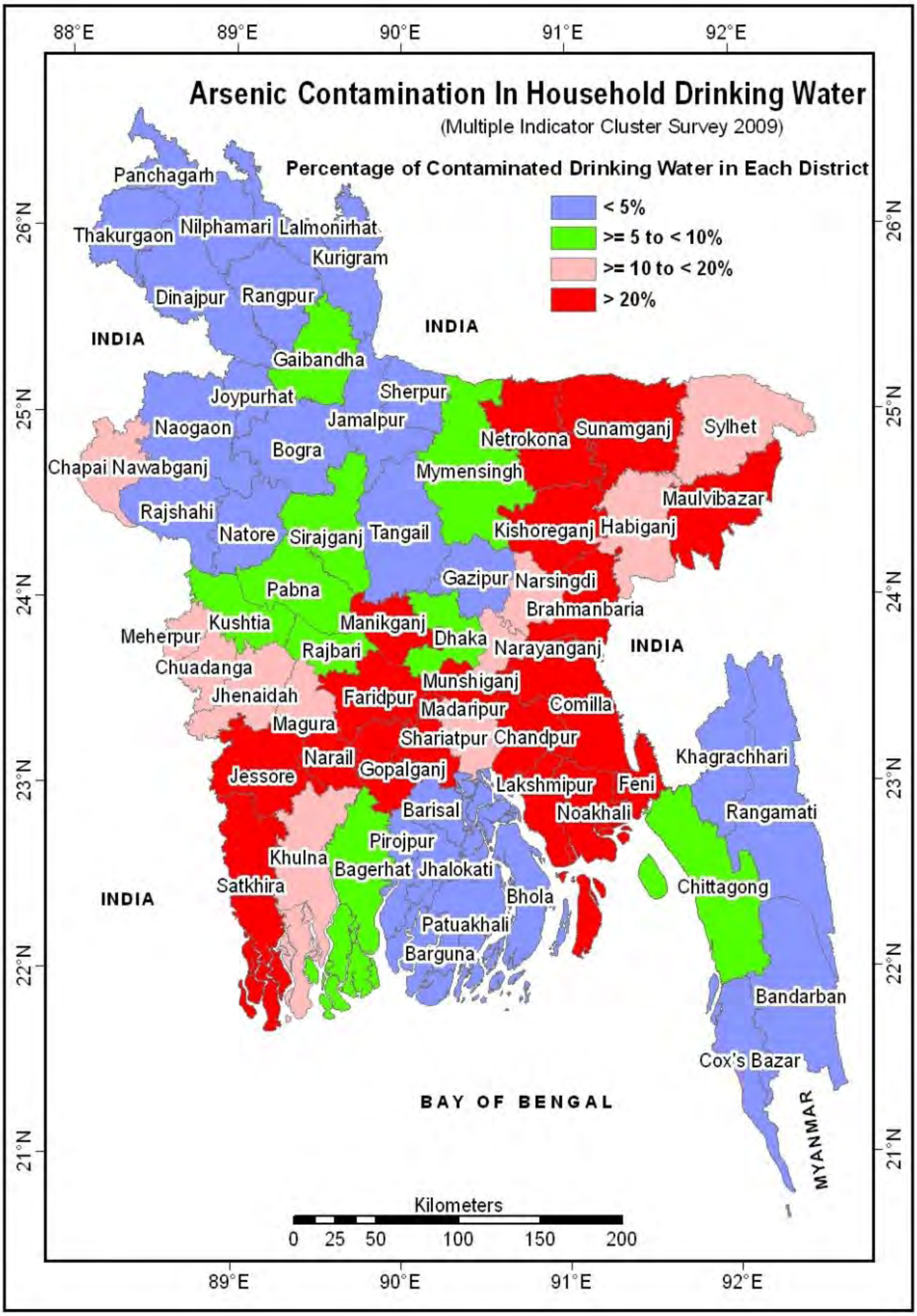


Figure 2-6: Arsenic Contamination in Household Drinking Water, MICS 2009

2.6 Salinity in Major Investigations

Very few studies have been carried out on salinity related issues especially on the groundwater salinity in large scale and detailed level. The related studies that have been executed are described briefly below.

Salinity distribution under FAP-4

The southwest region water management project (FAP-4) aimed to provide a management plan for land and water resources. One of the key elements of this plan is groundwater, which is a major source of potable water and irrigation supply within the project area. In recognition of the potential for groundwater development, hydrogeological component was incorporated in the study to provide assesment of groundwater resources where issues considered are abstraction and recharge, aquifer properties and water qualities along with salinity. The study tried to relate freshwater and saline groundwater interaction as a conceptual state not in detail. The study shows the following points:

- presence of a saline front and lenses of freshwater inthe upper aquifer
- Presence of saline wedge in the main aquifer
- Existence of hydraulic continuity between groundwater and rivers.

In the aquifer the position of saline fronts can be controlled by regional flow of groundwater towards the sea and the prevailing recharge conditions. In addition freshwater lenses may occur, overlying the saline water. Under natural conditions only minor seasonal changes take place in these relationship between fresh and saline water. The portion of saline wedge in the deeper aquifer is even less well defined. Its position is again controlled by southwards groundwater flow from northern parts of the project area and over abstraction within the region will tends to cause the wedge to move Inland, thus putting the existing irrigation wells at risk. The groundwater has the potentiality to make advarse changes. The over abstraction of the groundwater for irrigation at upstream, for example, the unconfined aquifers of the Khustia-Jessore areas will tends to move the saline front inland, resulting in more wells beginning to pumping brackish and saline groundwater. Simillarly, over abstraction or badly planed abstraction of water from the freshwater lenses will cause up-coming of saline water, with the effect of turning the wells saline (Afroz, 2011).

Soil and groundwater salinity in coastal areas of Bangladesh

High salt concentration is limiting crop intensification in the coastal zones of Bangladesh. Salt enters inland through rivers and channels during the late part of dry seasons when the southwestern freshwater flow becomes low. Salts also enter the solids by flooding with saline river water to concentrate in the surface layers through evaporation. River water causes an increase in salinity of the groundwater and possibly makes it unsuitable for irrigation. Salinity causes unfavorable environment over prevailing hydrological condition, to restrict intense crop production throughout the year. Thus, the soil and groundwater salinities are making rabi including boro cultivation difficult (PRDI, 2007).

Salinity problem and crop intensification in the coastal regions of Bangladesh by BRAC

In Bangladesh over 30% of the net cultivable area is in the coastal region. Out of 2.85 million ha of the coastal and offshore areas about 0.833 million ha is the arable land. This constitutes about 52.8% of the net cultivable areas in 64 upazilas of 13 districts are affected by varying degrees of soil salinity. Agricultural land use in these areas is very poor, which is much lower than the country's average cropping intensity (Afroz, 2011).

The freshly developed alluvium from upstream in the coastal areas of Bangladesh becomes saline once it comes in contact with seawater and continuous to be inundated during the high tide and ingress saline water through creeks. The factors which concentrate significantly to the development of saline soils are:

i) Tidal flooding during wet season (June-October)
ii) Direct inundation by saline water
iii) Upward or lateral movement of saline groundwater during the dry season (November-May).

2.7 Health Issues

2.7.1 Arsenic

Chronic arsenic poisoning, arsenicosis, can increase the risk of several health hazards including skin lesions, cancers, restrictive pulmonary disease, peripheral vascular disease, gangrene, hypertension, non-cirrhotic portal fibrosis, ischemic heart disease, and diabetes mellitus. Skin changes due to arsenic poisoning include a raindrop pattern of pigmentation and de-pigmentation that is particularly pronounced on the extremities and the trunk. Although less common, other patterns include diffuse hyper-pigmentation (melanosis) and localized or patchy pigmentation, particularly on skin folds. Hyperkeratosis (hardened skin) appears predominantly on the palms and the planter surface of the feet. Skin cancer resulting from chronic arsenicosis is quite distinctive. Multiple lesions are common and involve covered areas of the body, contrary to non-arsenical skin cancers which usually appear as a single lesion and which occur in exposed parts of the body (DPHE/ JICA, 2010).

Toxicity of arsenic depends on its accumulation in the body. The time taken to develop symptoms in the human depends on the exposure, body defense mechanism, nutritional status etc. It is thought that it may take 2-20 years to develop symptoms.

The arsenic poisoning from the contamination of ground water is very chronic in nature. Most of the time the victims do not complain of the above symptoms until they are detected through screening. The above symptoms are also very difficult to identify from other clinical conditions. The present experience to identify the arsenic cases are by external manifestations especially with the presentation on the skin called melanosis (blackening of skin) and keratosis (hardening of palms and soles) with the history of consuming arsenic contaminated source water.

Gangrene of peripheral organs and ulceration due to toxic effect on the small blood vessels may also be found. Cancer of the skin along with cancer of some internal organs - liver, kidney, bladder is not uncommon. The stage of keratosis is known as potentially malignant. It is also observed that even if a person having no manifestations after consuming contaminated water the chance of having cancer cannot be ruled out.

It is very difficult to differentiate the arsenical manifestation in stages. A person without external manifestations may face serious consequences of arsenicosis leading to cancer or acute renal failure. This is very simple to classify the arsenicosis as subclinical and clinical form. Clinically the earliest sign in the skin may be the melanosis then the keratosis and others. The systemic involvement is variable and may appear before and after the melanosis or keratosis. Subclinical cases deserve early identification and follow-up.

Experiences from the observation suggest that at least some stages of arsenicosis (melanosis) are reversible if the contaminated water consumption is stopped. The use of arsenic free water may probably stop the deterioration of the symptoms but information of complete recovery is not yet known. The supportive treatment for nutrition improvement may play some role to diminish symptoms and may help to reverse some cases of the melanosis stage.

Nearly 40,000 people showing the skin lesions symptoms characteristic of arsenicosis have been identified in Bangladesh. Studies have shown exposure to arsenic contaminated water can also cause impaired cognitive development in children. Malnourished people are twice as likely to develop arsenicosis as well-nourished people.

2.7.2 Salinity

Increased salinity of drinking water is likely to have a range of health effects, including increased hypertension rates. Large numbers of pregnant women in the coastal areas are being diagnosed with pre-eclampsia, eclampsia, and hyper tension. We reviewed hospital records of antenatal check-ups between January and September, 2007, from the Department of Gynaecology in Chalna Upazilla Health Complex—a clinic based in one of the ports in the southwestern region of Bangladesh. Of 561 women undergoing antenatal check-ups, 118 (21%) between the ages of 16 and 40 years were diagnosed with some kind of hypertensive disorder. This rate is strikingly higher than the 2·65% seen in Matuail (Sameena Chowdhury, personal communication), a non-coastal area, and the prevalence of pregnancy-induced systolic and diastolic hypertension of 6·8% and 5·4%, respectively, in another non-coastal rural community of Bangladesh. Although local doctors and community representatives have blamed the problem on increased salinity, no formal epidemiological study has been done. With both perinatal and maternal mortality remaining persistently high in Bangladesh, an urgent assessment of this situation is warranted.

2.8 Social Impact of Arsenic

People with arsenic poisoning suffer enormous social stigma in Bangladesh. Many people believe arsenic poisoning is contagious or a curse. Parents are reluctant to let their children play with children suffering arsenic poisoning and patients can be shunned within their villages. For women, the situation is worse. In Bangladesh, a woman's attractiveness lies in her beauty which is often judged by her pale complexion. This makes it harder, in some cases impossible, for single women suffering from arsenic poisoning to marry. Once married, women face the risk of divorce if they develop arsenicosis skin lesions. This can be a dire situation in Bangladesh's male-dominated society, where unmarried women are more vulnerable to poverty and social exclusion. Women are also less likely to receive early diagnosis or treatment.

2.9 Arsenic and Salinity in Comilla District

BGS/DPHE, 2001 report deals with the Arsenic problem in Bangladesh and also hydrogeology, hydro-geochemistry and mineralogy of three special study area including Lakshmipur near Manohorganj Upazila. According to this report, Meghna basin is one of the most severely affected areas of Bangladesh where 60-90% of hand tube wells (HTWs) are pumping water with arsenic above Bangladesh drinking water standard of 50 μg/l. Another hydrogeochemical study along the E-W transect in Meghna Basin and this study also mentioned the occurrence and origin of the groundwater salinity of both shallow and deep aquifers of this region.

DPHE & JICA, 2010, Borelog Data Book (Chittagong Division), is a compilation of some selected lithologs and their position in a location map. This book includes borelogs data of about 22 deep well present in Manohorganj Upazila. All of these wells were installed in the year 2005 and were drilled up to 200-250m depth. Water quality of these DTWs is quite good as arsenic concentration is very low. However, higher chloride concentrations in some places indicate presence of possible saline pocket in subsurface.

CHAPTER 3 : METHODOLOGY

This chapter presents the sequential description of different steps followed during study. The methodologies employed in the study are mainly secondary data collection, borelog data interpretation, slurry testing, water quality testing and mapping, questionnaire interview using PRA tools to assess the technology performance considering socio-economic, climatological and hydro geological context. The data collected in the study were both quantitative and qualitative. Figure 3.1 shows a flow chart presenting the methodology followed for the study.

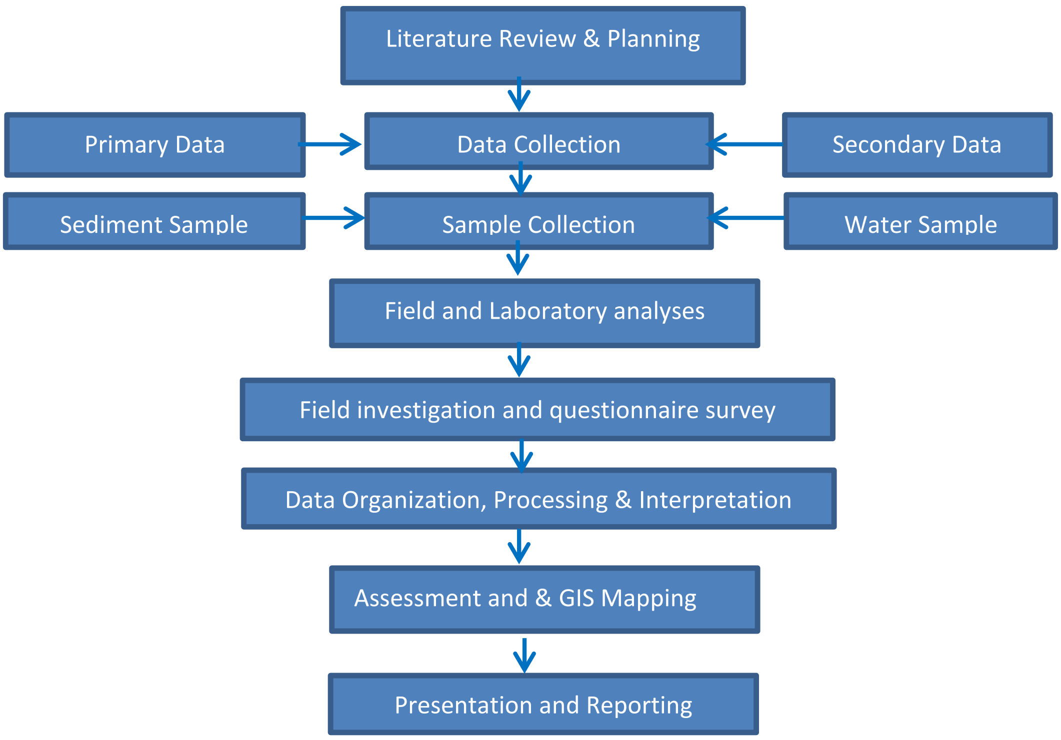


Figure 3-1: Flow chart for the methodology applied in the present study

3.1 Literature review and Planning

A number of research works have been done on Arsenic Contamination and Mitigation Technologies and many nationwide arsenic test programme have been done during last 15 years. To date arsenic mitigation in Bangladesh has been spread wide and thin, and often ineffectively. The optimism and ambition of earlier days have disappeared. Arsenic mitigation is stagnating; it has become unfashionable; and meanwhile the health of the exposed population deteriorates. Also there is lack of research and mitigation initiatives to deal the salinity problem in coastal and pocket areas of Bangladesh. After reviewing different relevant research paper and report it has been understand that appropriate technology is crucial for different context or hydrogeological situation. It could be more than one in a smaller geographic area such as a union. Acceptance by the people and O&M are also critical for the sustainability of any technology.

3.2 Data requirements and collection

Secondary data has been collected from various sources and primary data has been collected from field area. Necessary secondary data like rainfall, evaporation and water level data were collected from Bangladesh Water Development Board (BWDB), temperature data from Bangladesh Meteorolical Department, 10 borelog data from the DPHE, water table data from DPHE, Water Quality data from VERC- UNICEF. Other relevant data collected are Google earth image and Digital elevation map etc. Most of the data used in this research work are primary data collected during the field work at the study area.

Following primary data has been collected from the field for the study:

- 55 Borelog data collected for identifying aquifer characteristics
- 55 Slurry test data collected to identify fresh zone and correlate with water testing result.
- 33 STWs tested for arsenic with field test kit
- 33 Water table data from DTWs and 12 water table data from STWs has been collected
- 48 water sample has been tested in BUET lab for arsenic, iron, chloride and manganese
- 15 water sample from RWHs has been tested for TTC with field test kit (Pota-Test)
- 48 technology sites surveyed
- 226 household visited and completed questionnaire survey for socio economic assessment

- GPS location of 534 DTWs(DPHE, NGO & others), 55 borelog sites, 33 STWs sites and 45 Water table collection sites have been taken

Following secondary data has been collected from various sources:

- Water quality data of 117 DTWs with GPS location has been collected from VERC – UNICEF project to develop water quality mapping
- GPS data of 191 DTWs and 29 RWHs from VERC – UNICEF project
- DPHE Water table data of STWs has been collected from 1987 to 2010 to prepare time line variation
- Rainfall data collected from BWDB to produce rainfall hydrograph

3.3 Borelog analysis and slurry test

Bore log construction and analysis

55 borelog data (5 from each 11 unions) collected during new Deep Tubewell installation by VERC in the Manohorganj upazila. Only 21 wells had the continuous samples necessary for construction of bore log. These tube wells were constructed using manually operated rotary drilling method with the help of donkey pump. Depths of the wells are ranged from 640 to 820 feet (195 to 250 m) and samples were collected at 20 feet interval. Bore logs were prepared during the field work (Figure 3-2) from raw sediment samples with observed sediment colour. A sample has been attached as Annex 1.

Figure 3-2: Sample collected at 20 feet interval during drilling

Slurry Conductivity Tests

Slurry Conductivity tests have been carried out (Figure 3-3) during drilling of new wells during the study period to try to avoid installing deep wells in brackish aquifers. 55

sediment samples were collected from screened depth interval of 55 newly installed tubewells during boring and bore log collection. The key objective of the slurry conductivity test in the field is to identify suitable layer for fresh drinking water that contains salt within acceptable limits for well installation.


Figure 3-3: measuring EC of slurry

Slurry: a semi- liquid mixture of particles and water, in this case, a mixture of aquifer sand and water.

Conductivity: Electrical conductivity (EC) is a measurement of the ability of an aqueous solution to carry an electrical current. Conductivity reflects TDS and hence salinity in water. The measurement detects all ions from the dissolved salts. Electrical Conductivity can be measured in the field with a portable EC meter and expressed as μS/cm, or mS/cm.

Slurry Test Protocol:

A protocol for slurry test has been developed under this study with guidance from UNICEF Technical Specialist and supervisor. This protocol has been followed for testing EC of each of the 55 wells.


Figure 3-4: collecting sample for slurry test

Test Equipment:

1. Portable EC meter with conductivity standards
2. A pre-made scoop or cup calibrated to contain 10 g of sand
3. Distilled water
4. A pre-calibrated 75 ml container
5. A large cup or glass

Test Procedures: (Picture)

1. The large cup is rinsed with distilled water or bottled water three times;
2. 75ml distilled water or bottled water is measured and added to the large cup.

3. Electrical conductivity of the water is recorded.
4. Sand from a specific depth (Figure 3-4) is filled to a pre-calibrated scoop/cup to top.
5. 20 gm sand is poured into the large cup with water.
6. Sand in the cup is swirled and stirred for 1-3minutes and then waited for 1 minute
7. Again the cup containing sand is swirled and stirred for 1 minute and then waited for at least 15minutes.
8. Electrical conductivity is measured from the overlying water in cup. Probe is not allowed to touch the sand at the bottom of the cup.
9. Electrical conductivity is recorded once it has stabilized.
10. Records are kept.

Assessment and decisions:

The slurry test results to be assessed at different depths during a DTW drilling to take decision of suitable layer for screens. It has been observed from the lab and field test that layers showing conductivity of less than 60 μS/cm in slurry test is producing fresh water of less than 2000 μS/cm.

Precautions:

1. The sand samples should be drained properly before slurry test so that it loses all the drilling fluid (water).Tissue paper can be used, if necessary, to dry the samples.
2. EC meter should be calibrated before use and the probe should be rinsed before every measurement.

(Considering field situation, 10g scoop/measuring spoon were used to measure sand samples and a cup instead of beaker. Available 75ml dropper /tube/ bottle has been used to measure 75ml distilled water. Bottled drinking water has been used instead of distilled water)

3.4 Water sampling and water quality testing

3.4.1 Field Testing with Field Test Kit

Arsenic contamination in shallow wells and its severity data has been collected from local DPHE and DPHE/JICA Situation Analysis Report 2010 to understand the severity of the arsenic contamination in Manohorganj upazila. In addition, 33 water samples (3 per each 11 unions) from Shallow Tubewells has been field tested for arsenic (Figure 3-5) to get the clear picture and to produce severity map.


Figure 3-5: Arsenic test of STWs with field test kit

Physicochemical parameters such as pH, EC and Microbiological Quality were measured at 48 sampling location (Figure 3-6) during water sampling for lab test. pH and Thermo-tolerent Coliform (TTC) were determined at the site of 15 Rainwater Harvesting site that were selected for Questionnaire Survey.

Water was taken in a beaker and the parameters were measured immediately.

- Temperature was measured using the temperature probe of the portable EC meter.
- Electrical conductivity of the groundwater samples was measured using portable EC meter (HANNA DiST 5- HI98311).
- pH of the groundwater samples were measured using portable pH combo meter (HANNA- HI 98121).


Figure 3-6: Microbiological testing with POTA- Test kit

- Arsenic of the groundwater samples were measured using Econo- Quick test kit.
- Thermotolerent Coliform were tested (Figure 3-6) using membrane filtration and incubation through Wagtech POTA-Test kit. All necessary hygienic procedures has been maintained during on spot testing. All the equipment used in the testing (including sampling cup) were sterilized with methanol.

3.4.2 Laboratory Testing

Total 48 water samples from various newly installed technologies, such as Deep Tubewells that are slurry tested to avoid brakish water , Rainwater Harvestings, Piped water, Solar water purifier and arsenic removal units in all 11 unions. The water samples from these technologies have been taken to analyze the Water Quality performance. These samples were tested in BUET laboratory. Water samples were taken in 500 ml bottle and carried to BUET as early as possible after sample collection.

Water Sampling Protocol:

Following sampling protocol were maintained during the water sampling for testing chemical parameter such as; arsenic, chloride, iron and manganese:

- The bottles were labeled on the spot.
- Relevant site information including details of the location, type of the pump, depth, etc. was recorded in a data sheet during sampling.
- Before taking samples tubewells were pressed for at least 10 minutes.
- Sample bottles were rinsed three times with the filtered water sample.
- All of the sample bottles were filled in such a way with the filtered water sample so that no empty space was left in the bottle.

3.5 Field investigation and questionnaire survey

For technology assessment of 15 villages had been selected, where 240 households were interviewed. Sampling method had been applied to select the number of household and community.

Questionnaire had two parts, one covering the technical aspects through direct observation and data collection from field and another to cover socio- economic and sustainability aspects.

The following alternative sources and removal technologies had been assessed in terms of the performance and acceptability:

1. Deep Tubewells (DTWs)
2. Rain Water Harvestings (RWHs)
3. Piped Water Scheme

4. Solar Water Purifiers
5. Arsenic Removal Technologies

To assess the performance and acceptability of technologies field data were collected including water quality, quantity, yield per day, number of users, cost effectiveness, peoples' perception of technologies on affordability, operation and maintenance, user friendliness, availability of spare parts/ media, willingness to pay, etc..

Water table data has been collected from 11unions both for DTWs and STWs and analyzed accordingly. GPS location has been taken to produce GIS map to understand the overall situation of water table in this upazila.

Figure 3-7: Questionnaire survey at household level

For technology assessment questionnaire were developed for Household interview and Focus Group Discussions (FGDs) and field tested before finalizing (Annex- 3 and Annex-4). Local people had been engaged as support hand to find out the location and carry out survey. Different groups of people of the study area (men, women, low income and very low income people) using above technologies were identified and consulted through questionnaire survey at individual household level (Figure 3-7) and community level (Figure 3-8).

Figure 3-8: FGD at community level

Sample Size for Survey:

Safe water coverage at Manohorganj was 27.8%. It has been observed that a minimum of 10% change happened over time of one year intervention duration which is 37.8%. For calculating sample size STATA sampsi command has been used for one sample and assumed a design effect of 1.25, power of 0.8, and α of 0.05. The sample size calculation resulted 235 households would need to be surveyed. A very minimum design effect 1.25 has been used as the clusters would be from the same upazila where hydro-geological condition and socio-economic status are almost similar in nature. The proposed study considered 15 clusters that will cover 235 households. 16 households from each of 15 clusters has been considered that would bring a round figure sampled size 240.

In selecting 15 clusters (in fact 15 villages) out of 175 villages, the study used probability proportion to size (pps) of population sampling technique. Later on in selecting 16 households from each cluster, the study used systematic sampling technique. In doing systematic sampling, the surveyor travel to the center point of each cluster /village. The household nearest to the center point of the village was the first eligible household. For selecting the second household, the surveyor skipped the nearest 5 households and will choose the next one. Skipping 5 nearest 5 households continued until choosing a total of 16 from a cluster.

In order to have a representativeness of rain water harvest facilities out of 29 installed facilities, the study conducted survey to additional 15 households those are the direct beneficiary of rain water harvest facilities.

Five unions had been selected randomly from where 15 villages (3 villages per union) were selected on the basis of technology available. A detail plan was prepared (Table 3-1) based on that questionnaire survey were conducted.

Table 3-1: Plan for Household Questionnaire interview

Type of Technology	**# of Technology**	**# of HHs/ Technology**	**Total # of HHs**	**Total # of HHs finally surveyed**
Deep Tubewells	31	5	155	150
Deep Tubewells- Multiple Connections	5	2	10	10
Piped Water Scheme	1(10 Tap stand)	45	45	46
Rainwater Harvesting	15	1	15	15
Solar Water Purifier	5	1	5	5
Sono filter	5	1	5	Not found*
Alcan/ Read-F	5	1	5	Not found*
			240	226

* Not found means they were not found in place/ in use during survey time

3.6 Data Organization, Analysis and Interpretation

Water quality map of different parameters such as arsenic, iron, manganese, chloride, etc. were developed at different point of time and hydro-geological mapping of aquifers were developed based on bore- log data that will contribute in future planning and selecting area/ zone specific appropriate safe water technologies. Raw data collected from different domain (hydrometeorological, hydrogeological, hydrochemical and socio- economical) were processed to make it suitable for presentation and interpretation.

Hydrometeorological data:

Rainfall data (from 1991 to 2011), Evaporation and Temperature data (from 2000 to 2011) of the study were processed and organized using Excel spreadsheet. Long-term rainfall hydrographs were prepared to understand the climatic variations.

Hydrogeological data:

Lithologs constructed from the boring samples of deep tube wells were used to evaluate the subsurface lithology and hydrostratigraphy of the study area. From all prepared bore logs lithology types observed in the field were reduced and recoded (Table 3-2) and hydrostratigraphic zones were identified. These litholog data were then organized by excel spreadsheets and imported to GIS for creating 3D block diagram, lithologic and stratigraphic cross section and hydrostratigraphic model, etc.

Table 3-2: Lithological Table

Name used primarily	Recoded Name	Name used primarily	Recoded Name
Clay	Clay	Fine sand	Fine sand
Clay with silt	Silty clay	Fine sand with mottled clay	
Silty clay		Fine sand with silt	
sandy clay		Fine to medium sand	
Clayey silt		Fine to very fine sand	
Silt	Silt	Medium sand	Medium sand
Sandy silt		Medium to fine sand	
Silty sand		Medium to coarse sand	
Very fine sand		Coarse to medium sand	
Very fine sand with silt		Coarse sand	

Similarly static groundwater table data of shallow and deep aquifer were organized and analysed by Excel spreadsheets. GIS Map has been produced to understand the situation of groundwater static water table.

Hydrochemical data:

Water Quality data were organized by Excel and processed to analyze water chemistry and delineate water types and also for some statistical analyses. Arc GIS 9.3.1 mapping software was used to generate well location map, thematic maps and different spatial distribution maps.

Technology Assessment data:

Appropriate water technologies that are safe and sustainable has been recommended based on performance assessment that includes identification of fresh aquifer, analysis of water quality, timely and seasonal variation of water table, agricultural interference / dependency on groundwater, efficiency of technologies, users' perception and acceptability, operation & maintenance and cost effectiveness.

CHAPTER 4 : STUDY AREA

4.1 Study area selection

The newly formed upazila, Manohorganj (Figure 4.1), has been classified as a most under developed upazila in Comilla district. It was left out from the donor supported projects, as well as the regular government projects, due to administrative reasons till 2010. DPHE, in association with JICA has found out that 255 unions of Bangladesh face extremely low safe water coverage at less than 20%. Manohorganj is one of them, where all 11 unions are fall in to this extremely low coverage category with more than 98.8% arsenic contamination in Shallow Tubwells (DPHE/ JICA, 2010). More than half of this shallow wells contain >200 µg/L of arsenic at which level 1 in 50 people could die of cancer. Moreover, maximum numbers of suspected arsenic patients (4172) have been reported from this Upazila with severe skin lesions and gangrene (MICS, 2009), who have no alternative safe water sources.

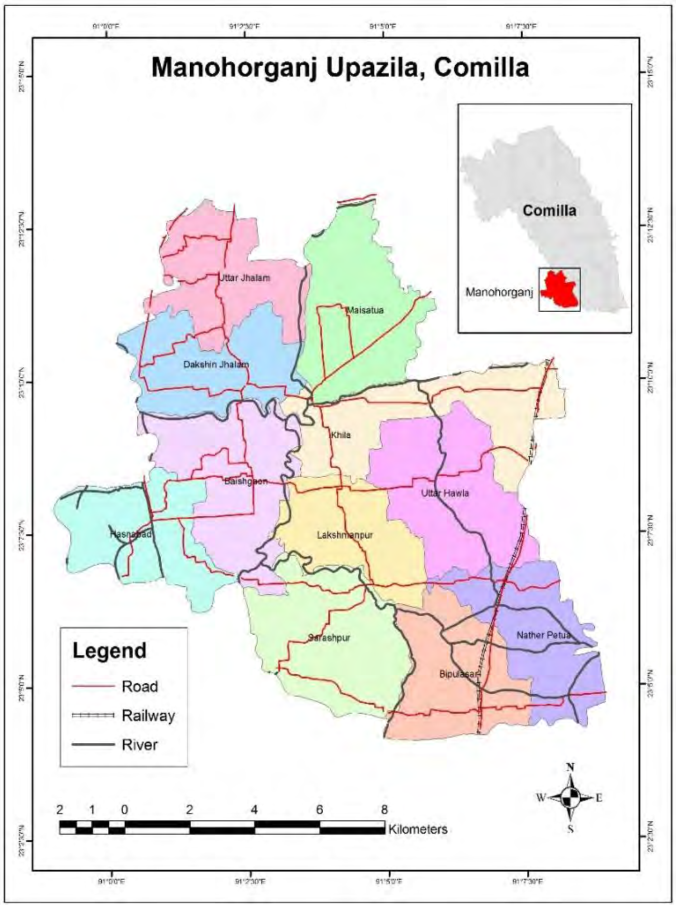


Figure 4-1: Map showing the location and communication of the study area

In this circumstances, a national NGO, Village Education and Resource Center (VERC) with financial and technical support from UNICEF, started working in this upazila to provide arsenic safe water to these severely affected people. When providing arsenic safe water sources they faced the other water quality problems such as iron, salinity and manganese. But the severity of these water quality problem were not known. There was no scope from the project to test non project wells or analyze. On the other hand, VERC has been tried many alternative options but were not confident which one is more feasible in which context of hydrogeological and socio- economic aspects. There was a strong feelings that a technological and social assessment is necessary for selecting appropriate, context specific and sustainable technologies in future.

From this crying need of Water Quality mapping and technological assessment, this upazila has been selected for the study.

4.2 Study Area Profile

Geographical Location, extent and accessibility

Manohorganj Upazila of Comilla district is located in the south-eastern part of Bangladesh and bounded by Laksham Upazila on the north, Chatkhil, Sonaimuri Upazilas of Noakhali district on the south, Nangolkot Upazila on the east and Shahrasti Upazila of Chadpur district on the west. It lies between 23°4’N- 23°14’N Latitude and 91°E- 91°9’E Longitude (Banglapedia,2003). The total area is about 41,143 acre. This newly formed Upazila (formed in 2005) consists of 11 unions, 145 mouzas and 161 villages.

The study area is well communicated with Dhaka and its adjoining areas both by roads and railways. The Upazila headquarter is connected with district town by metal roads and connected to Union parishads through a network of internal semi metal roads. Railway line passes through the area, which connects Dhaka District to north and Noakhali District to the south. The water transport system is local only during the monsoon season.

Population and Demographic Information

Population size of Manohorganj upazila is 2,44,943 with 1,12,339 (45.87%) male and 1,32,604 (54.13%) female. Total number of household is 44,847 with an average household size 5.5. Sex ratio is 85 (Male / female). Population density is 1,537 per sq.km. Disability rate is 1.8 % of the total people of the upazila (BBS, 2011). In the entire Upazila, around 35 percent are below 18 years of age (15.1 percent is ‘below five year’ and 19.9 percent is 10-18 years’). Women and children and people with disability require more attention when provide any sort of support especially Water and Sanitation services. The detail population and demographic information of each union of Manohorganj is given in the following Table 4-1:

Table 4-1: Population and demographic information of the unions of Manohorganj

Union	Total Household	Average household size	Total Population	Male (%)	Female (%)	Population density (/ sq.km)	Disability rate (%)
Baishgaon	4,639	5.4	25,091	11,350 (45.26)	13,741 (54.74)	1,501	2.1
Bipulasar	4,312	5.7	24,621	11,368 (46.18)	13,253 (53.82)	1,780	1.8
Hasnabad	3,431	5.4	18,774	8,621 (45.92)	10,153 (54.08)	1,425	1.1
Jhalam (Uttar)	3,883	5.5	21266	10,398 (48.89)	10,868 (51.11)	1,645	1.8
Jhalam (Dakshin)	4,274	5.1	21,982	9,920 (45.13)	12,062 (54.87)	1,589	1.3
Khila	4,172	5.4	22,609	10,489 (46.39)	12,120 (53.61)	1,280	2.1
Lakshmanpur	3,178	5.6	17,761	8,060 (45.38)	9,701 (54.62)	1,519	1.3
Maisatua	4,255	5.3	22,402	10,226 (45.65)	12,176 (54.35)	1,386	2.2
Nather Petua	3,999	5.7	22,561	10,308 (45.69)	12,253 (54.39)	2,518	1.4
Sarashpur	4,415	5.4	23,795	10,624 (44.65)	13,171 (55.35)	1,394	1.5
Uttar Hawla	4,289	5.6	24,081	10,975 (45.58)	13,106 (54.42)	1,392	3.0
Total	44,847		244,943	111,834.28 (45.90)	132,008.64 (54.10)		19.6

Source: BBS, 2011

Literacy rate and educational institutions:

Average literacy rate 48.74%; male 50.38%, female 47.19% according to BBS 2011.

Educational institutions: Degree college 3, college 1, secondary school 20, primary school 106, community primary school 12, kindergarten 18, BRAC school 42, madrasa 11.

Cultural and Social Information

Main means of livelihood are agriculture, fishery, agri -labor and business, etc. Main agricultural product includes rice, wheat, sugar cane and jute, etc. There are 01 Library, 38 Hat- Bazar, 4 Livestock Firms, 12 poultry, 6 Bank branches and 5 NGOs in entire upazila. There are also 3 Satellite clinic, 8 family welfare centre and 4 clinic.

Economic Status of the Households

According to VERC (presently working in this upazila) Baseline report 2012, 30% of the total population are poor and 16% are hardcore poor. The economic status of Hasnabad, Uttar Hawla and Jhalam Dakkhin unions are comparatively worst where more attention might be required while addressing the whole Upazila.

4.3 Water Supply Situation

Water supply at Manohorganj is dominated by tube well and most of the households about 88.8% drink tube well water. 98.8% of the Shallow Tubewells of the upazila have arsenic level above the Bangladesh drinking water standards (more than or equal to 50 ppb). In addition, the presence of salt, manganese, iron and odour problems in deep groundwater affects the use of deep tubewells. More than half the wells contain >200 µg/L of arsenic. By 2009, 4172 arsenicosis patients had been identified with severe skin lesions and gangrene in Manohorganj. Due to social pressures, many families conceal sufferers, and the true number will be higher. Despite huge efforts of sector actors, a situation analysis found that 255 unions (DPHE/ JICA, 2010) of Bangladesh face extremely low safe water coverage at less than 20%. All 11 unions of Manohorganj fall in to this extremely low coverage category. Union wise arsenic contamination, arsenicosis patients and safe water coverage has been shown in Table 4-2.

Table 4-2: Union wise arsenic contamination, arsenicosis patients and baseline safe water coverage

District	Upazila	Union	Arsenic contamination in STWs %	Arsenic patients	Baseline Safe Water coverage %
Comilla	Manohorganj	Baishgaon	98.8	564	18
		Hasnabad	99.4	393	12
		Maisatua	99.1	187	15
		Uttar Jhalam	98.5	874	21
		Dakshin Jhalam	99.4	850	18
		Lakshmanpur	98.7	149	14
		Nather Petua	99.4	537	9
		Bipulashar	96.9	98	19
		Sorospur	99.1	222	11
		Khila	99.2	173	10
		Uttar Hawla	98.5	125	11
Total/ Average			**98.8 (avg.)**	**4172**	**14.5 (avg.)**

Source: DPHE & JICA, 2010

Since June 2010, a national NGO VERC has been working with financial and monitoring support from UNICEF, to empower local governments, communities and schools ensuring sustainable interventions of arsenic-safe water, improved sanitation and hygiene behaviours in the worst-affected communities. Although safe water coverage in Manohorganj has increased from 14.5% to 31.6% (VERC Progress Monitoring Report, 2013) as a result of this project according to, there remains a large population in dire need of safe water. The type and number of technologies at a glance shown in Table 4-3.

Table 4-3: Technology at a glance in Manohorganj

Type of technologies	# of technologies	NGO_VERC	DPHE and others
DTWs	725	191	534
DTWs with multiple connections	63	63	
Rainwater Harvesting	29	29	
PWSS	1	1	
Solar Water Purifier	8	8	

Origin of groundwater salinity: Presence of salinity along with the Fe and Mn is another major issue regarding groundwater quality of the deep aquifer of the study area. Shallow groundwater is also having the same problem in some of the areas which has its effect on the irrigation of the area.

Demarcation between fresh water and saline water can be done using $Cl^-/HCO3^-$ molar ratio. Molar ratio of $Cl^-/HCO3^-$ >200 indicate sea water whereas fresh water usually shows $Cl^-/HCO3^-$ molar ratio less than 1. Normally molar ratio of $Cl^-/HCO3^-$ > 1 is the indication of sea water-fresh water mixing (Raghunath, 1987).

The molar ratio of $Cl^-/HCO3^-$ greater than 1 exist throughout the study area indicating marine water mixing with the fresh water and samples showing $Cl^-/HCO3^-$ <1 which is the indication of fresh water is also observed in different parts of the study area.

Groundwater trapped at depth in the alluvial aquifers in and around study area is notably rich in Cl^-. These ancient waters can be shown to be trapped sea waters which entered the aquifer during periods of the Quaternary when the relative positions of the land and sea were rather different than at present.

4.4 Sanitation Situation

Proper sanitation is the precondition of better health care. With the intervention of different programs of NGOs and spread of Community Led Total Sanitation (CLTS) approach, many people are aware about bad effect of open defecation. Also Social norms established to hate open defecation (OD) that has made people to stop such unhygienic practices.

According to baseline survey conducted by VERC in 2012, around 74% latrines are found hygienic. 26% latrines are found unhygienic (Table 4-4), which is a significant number. VERC has been working to promote effective sanitation in this upazila and taking various awareness initiatives.

Table 4-4: Sanitary Latrine Condition in Manoharganj upazila

Name of Union	**Condition (%)**	
	Hygienic latrine	Un- Hygienic latrine
Baishgaon	69	31
Sorospur	62	38
Hasnabad	85	15
Jhalam Uttar	86	14
Jhalam Dhakkhin	78	22
Maisatua	75	25
Laxmanpur	40	60
Khila	84	16
Uttar Hawla	81	19
Natherpetua	74	26
Bipulashar	69	31
Total	**74**	**26**

From the Table 4-4, Hygienic latrine coverage is highest in Jhalam Uttar union (86%), followed by Hasnabad and Khila unions (around 85% and 84%, respectively). As counting the number of households, there is a serious need to make efforts to convert a huge number of latrines into hygienic condition. In Laxmanpur union, around 60% latrines are unhygienic where serious motivational work would be required to ensure hygienic condition of 1,456 latrines. Number of unhygienic latrines is significant in all the unions; the range is between 493-1,456 households. Total 8,765 sanitary latrines have been found in unhygienic condition.

Therefore, more efforts should be given under various development projects to make people aware for keeping their latrine hygienic and practice hygienic behavior. It is a challenge against not only by increasing sanitary latrine coverage, but also to ensure sustainable and healthy use of latrines. Different types of motivational and ignition initiatives should be introduced by the implementing organization to ensure remarkable improvement on overall environmental status, sustainability of hardware and installation of improved technologies.

After 2 years of awareness campaign by VERC, it has been found that hygienic latrine use increased from 74% to almost 95%. Peoples are motivated and took necessary actions to make their unhygienic latrine to hygienic one or build a new hygienic latrine.

4.5 Hydrometeorology

Manohorganj falls in the south central zone of the climatic sub-division and it is characterized by heavy precipitation, high temperature and excessive humidity. Like other regions of Bangladesh, Manohorganj experiences three major climatic seasons i.e. a hot summer (March–May) with some storms, followed by monsoon (rainy) season (June–October) and a moderate winter season (November–February).

The temperature varies from near 10°C in winter to near 35°C in the peak of the summer. Maximum temperature rises over 30°C during summer and during this period maximum evaporation is observed (around 100 mm).The temperature distribution of the study area (Figure 4-2) influences both rainfall and evaporation.

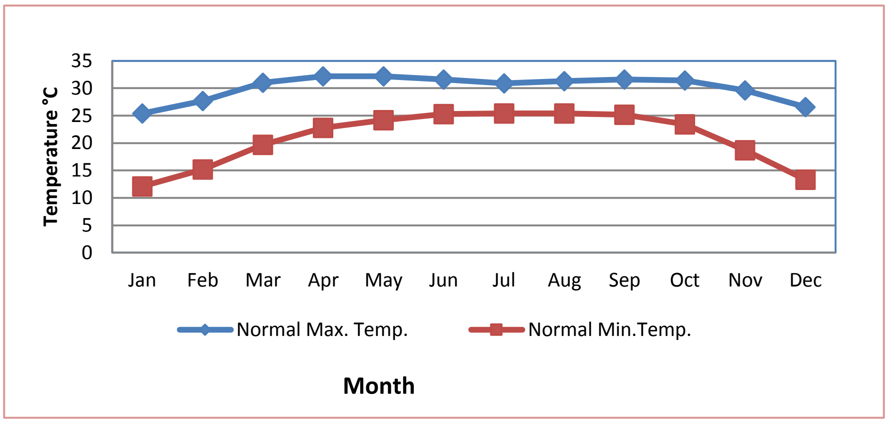


Figure 4-2: Maximum and minimum temperature of the study area

Rainfall hydrograph has been constructed from the daily rainfall data collected by Bangladesh Water Development Board (BWDB) for the period from 1995 to 2010. The average annual rainfall in Manohorganj is 1826.66 mm (considering the rainfall data from 1995-2010). Figure 4-3 reveals that rainfall is minimal during winter and part of the summer whereas monsoon period of the year receives abundant rainfall. According to DPHE water level data, groundwater level of the shallow aquifer of the study area changes with rainfall throughout the year and not varied significantly during last 10 years, indicating the direct recharge from surface water.

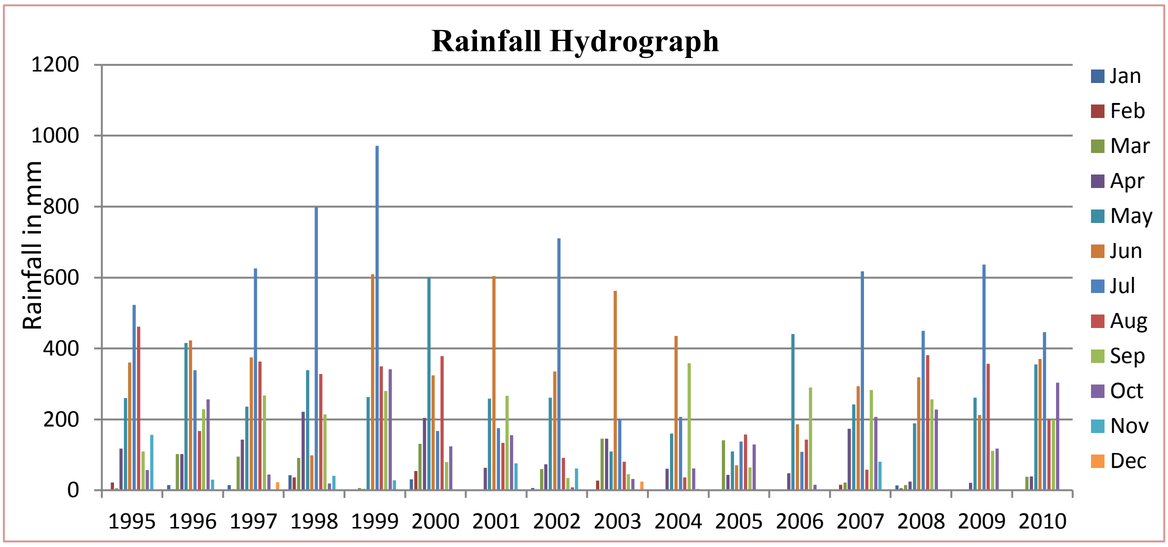


Figure 4-3: Rainfall hydrograph (1995- 2010)

4.6 General Geology of the study area

Physiography and drainage system

Physiographically Bangladesh can be divided into 7 divisions, namely Hilly Regions, Pleistocene Uplands, Tippera Surface, Tista Fan, Flood Plains, Delta Plains of GBM Delta Complex and Sylhet Depressions & Inland Marshes. Each of these divisions can be subdivided with distinguished characteristics of its own. Physiographically the study area is situated in the Tippera Surface division, which lies between the Meghna flood plain in the west and the Tripura Hills in the east and was uplifted in Early Holocene times.

The drainage system of the area is controlled by Dakatia River and its distributaries. Dakatia River is the main river flowing through the Manohorganj Upazila both along east-west and north-south directions and it shows distinct meandering pattern. The area is also drained by a network of canals (locally known as Khal). Dakatia River is one of the Trans-boundary rivers of Bangladesh. It enters the country from India's Tripura state at Bagsara of Comilla district. It is a tributary of the Meghna. The main source of the flow of this river was the Kakrai, but the Little Feni River cuts back and captured its upper portion. Total length of the Dakatia is about 207 km. Tidal currents feed the Dakatia through the Meghna for three-fourths of the year.

Geomorphology and surface Geology

The geology of the study area and its adjoining areas are controlled by the Quaternary sedimentation and the surface of the study area like most other regions of Bangladesh is covered with recent alluvial sediments. Like any other Deltaic and Flood Plain regions the surface of Manohorganj and adjoining areas is covered with alluvial silt and clay and alluvial clay deposits. Alluvial clay, also known as Chandina alluvium covered most of the portion of the study area. Only the north western portion of the study area has the surficial deposit of alluvial silt and clay.

Stratigraphy and depositional history

The study area covered with a thick sequence of deltaic and flood plain deposits of Quaternary age. Exploratory drill holes of BWDB and DPHE provide the litho-stratigraphic information of the study area including the water bearing zones. In the present study focus given on the Pliocene and Quaternary Stratigraphy of the study area as it forms the major water bearing aquifers. The lithostratigraphic units are:

1) Meghna Flood Plain Deposits
2) Chandina Formation
3) Madhupur Clay formation
4) Dupitila Formation

Hydrogeological setting

Based on the geologic criteria, lithology, thickness and structure of rock formations, four major hydrogeological regions has been recognized by experts in the country, that are;

I. Younger Alluvium
II. Complex Geology
III. Older Alluvium
IV. Coastal Area

The study area lies in the Older Alluvium.

4.7 Existing Arsenic Safe Technologies

Rural water supply in Bangladesh is predominantly based on ground water. But identification of arsenic in ground water particularly in shallow aquifer causes threat on ground water based water supply system. In addition, saline contamination in deep or shallow aquifer in coastal and some pocket areas are creating challenge in providing safe water.

The ground water of Bangladesh is extremely complex in terms of water chemistry and geology as well. On the other hand, protected but perennial surface water source is not available in many parts of the country. So, one technology may not be suitable for the larger areas because of different hydro-geological situation. In that case the water technology is required to be identified on priority basis up to specific boundary, such as union level considering the following issues;

- lowering of water table
- Arsenic contamination in ground water particularly in shallow aquifer
- Salinity in ground water
- Iron & Manganese in ground water
- Non availability of suitable aquifer or rocky/hard layer
- Non-availability of protected and perennial surface water source round the year

VERC, when started working in severely arsenic contaminated Manohorganj upazila in 2010, did preliminary assessment of possible technologies. They also discussed the finding with community and UNICEF to identify the potential arsenic safe technologies following "National Policy for Arsenic Mitigation 2004 & Implementation Plan for Arsenic Mitigation in Bangladesh". VERC- UNICEF also piloted two technologies to see the appropriateness in this context. Following technologies are found in Manohorganj upazila that are used as arsenic safe technologies provided mostly by VERC or DPHE.

Alternative Technologies:

a. Deep Tubewell
b. Piped Water Supply Scheme
c. Rain Water Harvesting

Arsenic Removal Technology (ART):

a. Sono Filter

Piloting Technologies:

a. Deep Tubewell with multiple connections (Piloting)
b. Solar Water Purifier (Piloting)

According to the National Policy, PSF and dug well will be tried first. If these technologies are found not feasible deep tubewell could be tried following the "Protocol for sinking Deep Tubewells in Arsenic contaminated areas". Dug/Ring Well and Pond Sand Filter considered initially but found not feasible due to technical reason. Few Dug wells were provided by DPHE earlier found abandoned due to bad quality water. Moreover, Dug wells found not feasible due to upper thick clay layer and high arsenic concentration in shallow aquifer. Pond Sand Filter found not feasible due to non-availability of protected and perennial pond water round the year.

According to project approach, water points installed through the process of community action plan (CAP). During preparation of CAP, the community provided with the understandable ideas about the water option so that they can rightly choice the option by themselves.

4.7.1 Alternative Technologies

The main feature and basic criteria for each of the option are presented as follows:

a. Improved Deep Tubewell

The deep aquifers in Bangladesh have been found to be relatively free from arsenic contamination. The aquifers in Bangladesh are stratified and in some places the aquifers are separated by relatively impermeable strata. Deep tubewells (Figure 4-4) installed in those protected deeper aquifers are producing arsenic safe water. Sealing in the impervious layer is done to prevent the leaching of arsenic through path way created during drilling of the well.

Basic Criteria:

- It can be installed where shallow aquifer is separated from deeper aquifer by substantially thick impervious layer.
- It can be installed in the coastal areas of Bangladesh having safe aquifer.

Design Requirements:

- The entire tube well should be installed straight and vertically deep bore hole is required therefore.
- The annular space of bore holes of the deep tube wells are required to be sealed at the level of impermeable strata.

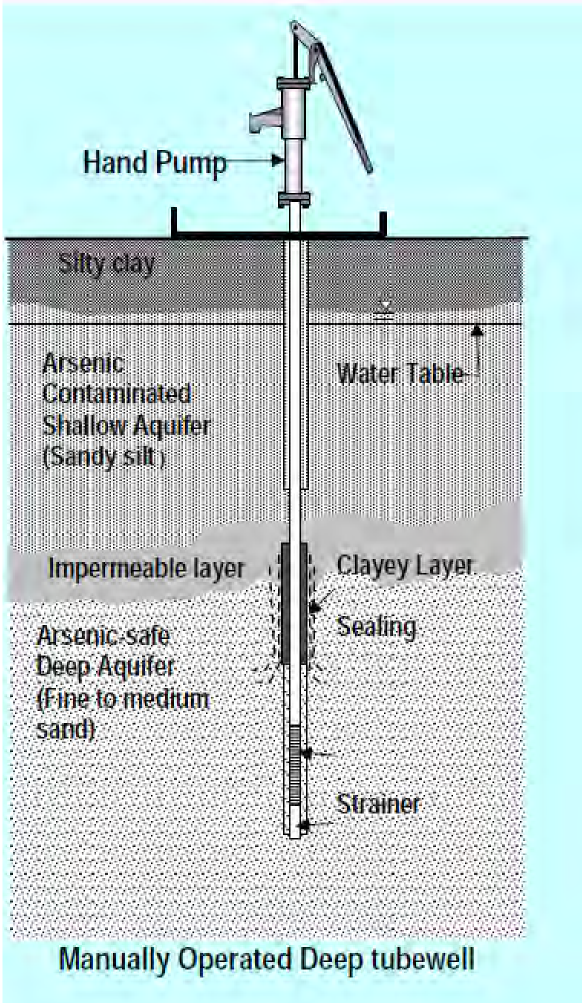


Figure 4-4: Manually Operated Deep Tubewell

In Manohorganj, initially DTWs were provided that are found mostly saline. After that slurry test advised to introduce as precautionary measure during drilling to avoid brackish water. It is supported by this study not from the project. Slurry tests (detail in methodology) conducted during drilling permits the layer with fresh water to be targeted for well installation, avoiding costly mistakes that a deep well is installed to brackish groundwater.

b. Piped Water Supply System:

This is the ultimate goal of safe water supply in rural Bangladesh because piped water is protected from external contamination and water can be delivered in close proximity to the consumers. It allows a more effective operational response and better quality control through monitoring. Institutional arrangements for operation and maintenance are feasible, and water of required quantity can be collected with ease. Rural piped water supply has received priority for arsenic mitigation in Bangladesh and a large number of pilot schemes by different organizations are under implementation. It is reported that the rural people in arsenic affected areas of Bangladesh are willing to pay for piped water. Piped water supplies are also possible for clustered households in villages, growth centers and the rural areas having good rural road network.

Basic consideration/ criteria

i) **Site selection and Social Mobilization:** In many ways this is the most important aspect, as many schemes fail due to the people it is meant to serve not having a good understanding about the system and not being able to operate and manage it well. Therefore some initial mobilisation is usually required to explain to villagers the possibility of a piped water system. This should include assessment of the following

- the community cohesiveness and ability to work together. This is important for forming an effective water user group and management committee
- the proportion of people willing to have (and pay for) a house connection,
- the people's ability and willingness to pay a monthly water tariff and to give an initial up-front contribution.

ii) **Ground water and water Quality:** The site of the proposed new source should be accessible for construction, and have sufficient space for any required treatment process and a nearby overhead tank. Additionally the source should ideally be in the middle of the area to be served and not at one end, thus making the pipeline more efficient. Where groundwater is to be used as the source, desk top exercises should be carried out to check aquifer yield and possible water quality issues. It is very helpful if a test well can be constructed at this stage, in order to:

- confirm availability of a minimum aquifer thickness at the preferred location of the well
- check aquifer properties and confirm the well will produce enough water
- carry out water quality tests and confirm what treatment will be required.

iii) Physical Infrastructure: The most important infrastructure consideration is to ensure availability of electricity near the proposed source site, for the running of the pumps (that supply water to the distribution network). Without this, the system will not work. The only exception to this is where an alternative means of pumping can be provided, such as solar pumps. However, care must be taken to be sure that such a pump will be able to operate at a suitable flow rate and head before accepting the site.
The likely route of the pipeline should be considered. Preferred schemes are compact, serving one community with few large gaps between groups of beneficiaries, whether because of fields or market areas. This is important as this will help in social mobilisation and operation of the scheme. Pipeline should stay on public paths and avoid passing though private land (e.g. fields). The pipeline should also avoid crossing rivers or canals although this can be considered if attached to the side of a bridge.

The location of the intended production well should be in an area with sufficient space for an overhead tank and possible treatment plant if needed. In Manohorganj there is a piped water scheme providing drinking water to around 2000 people.

c. Rain Water Harvesting

Rainwater Harvesting is a technology to collect rainwater for its use in drinking purposes. About 203 cm rainfall occurs annually in Bangladesh. The rain water is safe if it maintained hygienically. The main limitation of this option is non-availability of rain water round the year. But it can be widely used as supplementary source. As per "National Policy for Arsenic Mitigation 2004 & Implementation Plan for Arsenic Mitigation in Bangladesh" the government's role is mainly to conduct promotional activities for RWH.

Pre- requisite criteria

- Feasible where average rainfall is 1600 mm per annum.
- there should have required catchment area for rain water harvesting

Design Criteria

- Rain water has 3 basic units. 1. The catchment area (like corrugated roof top) and 2. Supporting collection system (gutter and pipe collection pipe) and 3. Storage tank.
- Catchment zone can be a corrugated tin-shed, sloped flat roof top, polythene sheet etc.
- The tank can be a made of GI, ferro-cement, burned clay (motka), plastic etc.
- The collection pipe should have an exit way beyond the connection with storage tank to let the first flush flow away.
- The down pipe should have net to bar mosquitoes, flies from entering into the storage tank.
- There should be an end plug to stop flush discharge to enter water into the storage tank after flushing.
- The location should be so selected that it allows accessibility of people.

Figure 4-5: Household Rainwater Harvesting System

In Manohorganj, Rainwater Harvesting System (Figure 4-5) has been promoted in some pocket areas which is difficult to reach with DTWs or with multiple connections or Piped Water Supply networks.

4.7.2 Arsenic Removal Technologies (ARTs):

ARTs are the chemical options which remove arsenic mainly using media. Four options are provisionally certified by BCSIR (Table 4-5) of which three are house hold and one is community based. These can be selected as a last resorts particularly where deep tubewell and Dug well is not feasible. Filter media have to be changed after the media being clogged. The quality of raw water is specified for each technology. The main features of the BCSIR's approved ARTs with flow rate and shelf life are given below:

Table 4-5: BCSIR's Approved Arsenic removal treatment units/ plant

Name of ARTs	Flow rate	Total Treatment/ shelf life
Sono (House hold)	16 lit/hr	8100 liter
Alkan (House hold)	120 lit/hr	8100 liter
Read-F (House hold)	60 lit/hr	40,000 liter
SIDKO (Community)	240 liter/hr	1,21,500 liter

a. Sono Filter (initially the 3 Kolshi System)

The 3-Kolshi System, which basically consists of three clay pots stacked vertically, was initially developed by the SONO Diagnostic Center in Bangladesh and it is based on an indigenous water treatment practice. Arsenic is removed by adsorption to iron filings contained in the top pot. A continuous improvement of the filter system has led to a new filter model, the SONO 45-25 filter. This filter technology has passed through several environmental technologies verification programs for arsenic mitigation (ETV- AM) projects. Recently, the filtration technology has been given the highest award from the National Academy of Engineering-Grainger Challenge Prize for Sustainability (Hussam & Munir, 2007).

The top layer built by coarse river sand (CRS) - an inactive material used as a coarse particulate filter, disperser, flow stabilizer and providing mechanical stability (Hussam and Munir, 2007) – yields to the oxidation of groundwater with high concentrations of soluble iron and precipitate as $Fe(OH)_3(s)$. Inorganic As(III) species – catalyzed by manganese in the composite iron matrix (CIM) - are oxidized to As(V) species by the active O_2 , which is produced by the oxidation of soluble Fe(II) with dissolved oxygen. The removal process of As(III) and As(V) is independent of the input arsenic concentration i.e., a zero-order reaction.

Complexion and immobilization of inorganic arsenic and many toxic metal cations occurs within the CIM, the primary active material. It is made of cast iron turnings through a proprietary process to maintain active CIM integrity for years (Hussam &Munir, 2007). Brick chips (BC) are a further inactive material and have similar functions as CRS. The combination of the two materials acts as a protection barrier for the free-flow junction outlet. Wood charcoal (WC) absorbs different organic material, such as pesticides and therefore the taste of the water is improved.

DPHE- UNICEF under DART project provided 12 Sono Filter in these upazila in 2009. Very few of them are physically found presently. Most of them are abandoned.

4.7.3 Piloting of New Technologies

a. Multiple Connections with DTWs

Deep Tubewells are preferred options by the community. To increase the access and cover more people at a time multiple connections (Figure 4-6) were introduced in Manohorganj which are also became very popular among the communities of Manohorganj.

A simple and manual water distribution system is achieved through connecting several No. 6 hand pumps horizontally to a single bore hole via PVC pipes with check valves. Traditionally, one No.6 hand pump is installed vertically above a bore hole drilled to a given depth to supply water. Modifications were made such that up to 4 No.6 hand pumps can be attached to PVC pipes buried at about 1.5 ft below ground to transport water over a distance of up to 760 ft. Using several hand pumps to draw water from a single deep bore hole can significantly reduce the cost of water supply, with an additional benefit of sharing a good point source of shallow or deep groundwater where good quality groundwater with low salinity, arsenic, iron and manganese is scarce. Areas in Bangladesh where this technology is applicable include arsenic affected areas where deep groundwater (> 500 ft) as a high water table of < 25 feet and coastal area where shallow groundwater is frequently brackish with an occasional fresh pocket.

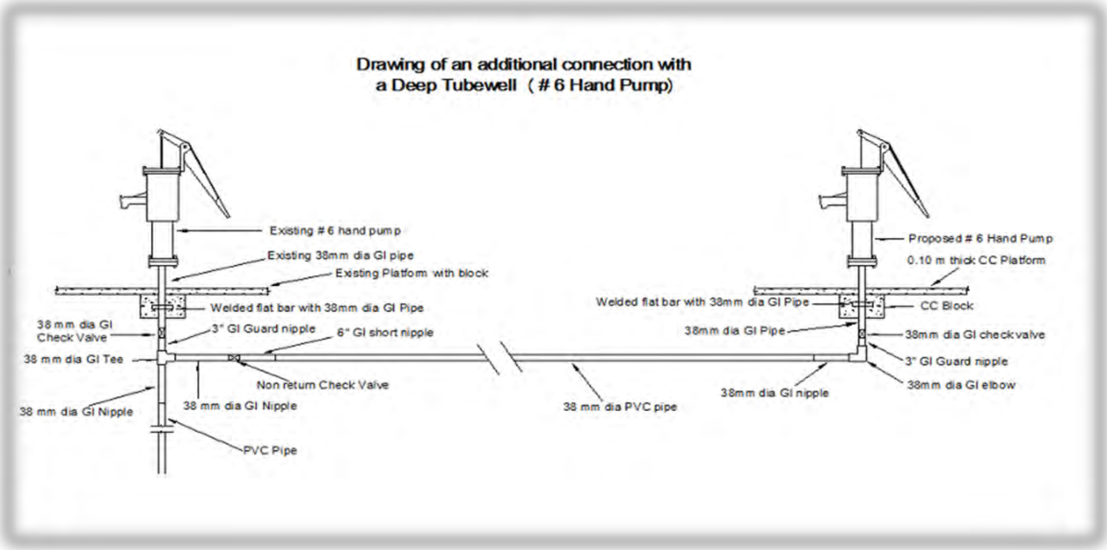


Figure 4-6: Tubewell with multiple connection

Pre- requisite criteria:

- Water table should be less than the suction limit of the No. 6 hand pump
- Existing water sources such as shallow tube wells have water quality problems.
- Existing deep tube well has excellent water quality with low salinity, arsenic, iron and manganese.
- Densely populated
- Space and paths are available for pipeline
- Bore hole should be located in an open area where connections can be made easily.
- The pipeline should avoid natural barriers such elevated land areas, canals and ponds, as well as to cross major roads.
- Community should be extensively consulted for locations of the bore hole.

b. **Solar Water Purification Panel:**

Although arsenic concentration is low in deep aquifer, presence of salt, manganese, iron and odor problems are affecting the performance of Deep Tubewells in some of the unions of Manohorganj. Considering the water quality context and pocket households, in March 2012 VERC installed 08 units of Solar Water Purification Panel as piloting.

Fcubed Solar water desalination Purification Carocell panel (Figure 4-7) uses solar radiation to vaporize the water and collecting condensation for its purified fresh water and can be used as a rainwater harvesting unit during the rainy season. Fcubed claimed that these Carocell Panels will have 20 years life span and this is the most cost effective purification system in the world. The most important material used to make the panel is poly- carbonate sheet which is made by German Pharmaceutical Company.

Figure 4-7: Carocell Water Purifier Panel in a Primary School at rooftop

Appropriateness /Suitability

i) Pocket areas that could not be addressed through community based safe water system

ii) Primary and secondary schools

iii) Coastal areas where shallow aquifer is contaminated with arsenic and deep aquifer is with saline

Advantages:

- Water quality meets the Bangladesh Standards for arsenic, iron, manganese, chloride and coliform according to BSTI and DWASA lab. Also tested by field test kit when installed at field
- No use of chemicals, no filters or media to replace, no fuel or electricity
- Rain water can be collected from the upper surface of the panel during rainy season.
- People accepted the water aesthetically as there is no taste or odor problem
- People accepted it as arsenic safe water
- The initial capital cost (panel cost and installation cost) is Tk. 28,000 per panel per household. It is costly considering the economic status of the average household. But

considering 20 years life span and no additional cost involvement for the regular O& M, the cost seems competitive.

Disadvantages:

- Difficult to install on ground level
- Risk of damage of poly carbonate sheet.
- Spare parts not available in local market.
- Risk of over- turning during heavy storm.
- Low flow rate and depends on sunlight
- Management of water is difficult as water collected per day is very minimum
- Security of panel is concern if it is on the ground
- Space problem at HH level
- Lift water to the intake is difficult

4.8 Summary of technologies in study area

In addition to arsenic in shallow aquifer, the presence of salt, manganese, iron and odour problems in deep groundwater affects the use of deep tubewells. Combining survey data has resulted in significantly improved targeting of Deep Tubewell installation. Multiple connection deep tubewells have also been promoted to serve more people with arsenic safe water in a cost effective way. Rainwater Harvesting (RWH) has been promoted to serve small and more isolated families, though it is more expensive and requires considerable maintenance. Solar distillation panels, a major innovation for water scarce area, have been piloted at household level and at schools. This may be applicable at least for isolated pockets of exposure and perhaps more widely where both aquifers have water quality problems. Piped Water Supply Scheme (PWSS) had been piloted to supply around 1880 people with proper distribution network and yard connections last year in Manohorganj. The management committee has been functioning well and are responsible for operation and maintenance, including caretaker selection, management and monitoring, O&M fund management, caretaker's salary, paying electricity bill, etc. Three more PWSS are in process to start implementation in three upazilas. The most appropriate water supply option is decided through consultation between the community and DPHE, with technical assistance from VERC and UNICEF.

CHAPTER 5 : RESULTS AND DISCUSSIONS

5.1 Introduction

In this chapter the results of the study has been discussed. The scale of water quality problem has been detected and water quality map of different parameters has been developed at different points of time. Hydro-geological characteristics has been discussed and mapping of aquifers has been produced based on bore- log data representing all unions. This results will contribute in future planning and selecting area/ zone specific appropriate safe water technologies. A questionnaire survey results has been discussed and assessed the performance and acceptability of technologies on water quality, quantity, peoples' perception on affordability of technologies, operation and maintenance, cost effectiveness, user friendliness, availability of spare parts/ media, willingness to pay, etc.. A GIS map of all safe water technologies has been developed to identify the future needs through identifying the number and spatial location of the population still uncovered by safe and sustainable water technologies.

Finally, based on these results and findings, existing technology performance matrix has been developed and future technology selection matrix has been produced.

5.2 Scale of arsenic problem in shallow aquifer of Study Area

Water quality analysis is one of the most important aspects in groundwater studies. Though, water safe for drinking on the basis of physical properties and chemical composition may not be bacteriologically safe. It is now generally realized that the quality of groundwater is as important as its quantity. Here, discussion will be made only on drinking water quality.

Manohorganj, the most severely arsenic affected upazila of Bangladesh, where around 98.8% of shallow wells are contaminated by arsenic. Out of total 11 unions of the study area, 9 unions fall in the very high priority area and other 2 unions fall in the high priority area for developing safe water option.

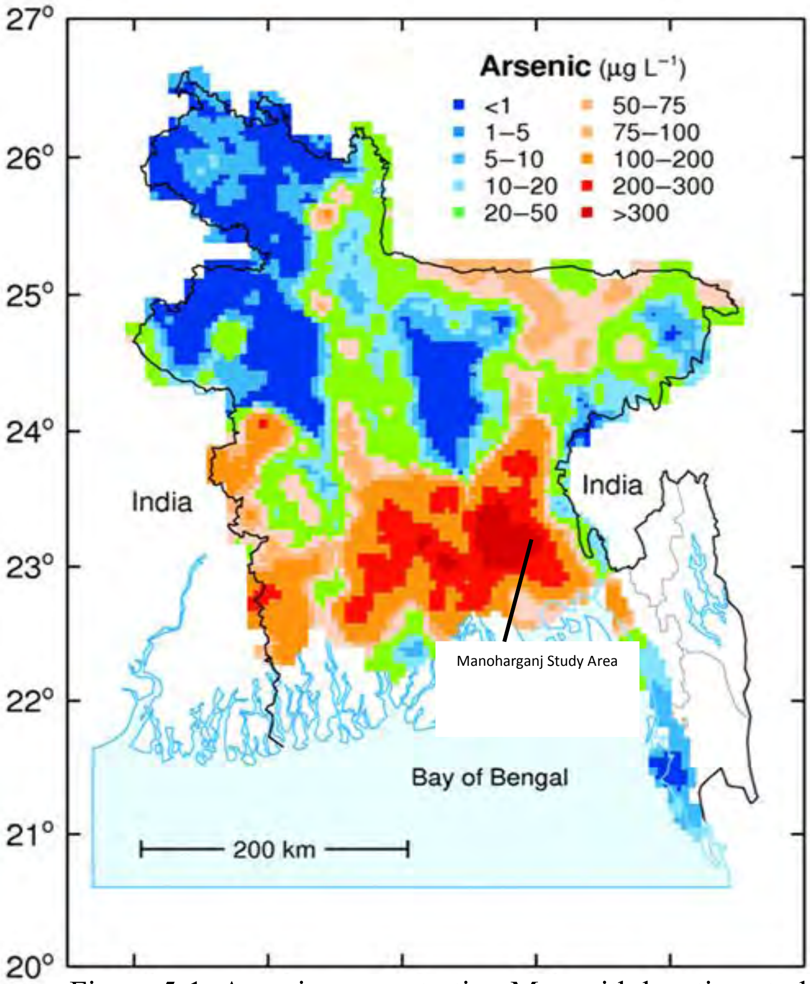


Figure 5-1: Arsenic concentration Map with location study area

To analyze the severity of arsenic in shallow tubewells, 33 water samples (3 samples from each union), has been collected and tested with arsenic field test kit (Econo- Quick). The test results showed high level of arsenic. More than 50% shallow tubewells are exceeded 500 μg/L and 100% are more than 300 μg/L (Figure 5-1). The test results are shown in Table 5-1 which is followed by concentration map in Figure 5-2.

By 2009, 4172 arsenicosis patients had been identified with severe skin lesions and gangrene in Manohorganj. Due to social pressures, many families conceal sufferers, and the true numbers will be higher. A few snap shot of arsenicosis patients in Figure 5-3 with brief case study of their sufferings has been provided. Few more pictures also added in Figure 5-4 to understand the sufferings and severity of the problems of the study area.

Table 5-1: Level of Arsenic Concentration in Shallow Tubewells (Union wise)

Sl #	Name of Owner	Union	Type of Tubewells	Installation year	Depth (ft)	Arsenic (mg/L)
1	Abu Taher	Khila	STW	1978	80	0.5
2	Jashim Uddin	Khila	STW	2013	60	0.5
3	Shahjahan Kabir	Khila	STW	2010	70	0.5
4	Md. Younus	Natherpetua	STW	2005	70	0.5
5	Kazi Golam Mostafa	Natherpetua	STW	1994	350	0.5
6	Mobarak Hossain	Natherpetua	STW	2008	60	0.3
7	Bazlur Rahman	Bipulasar	STW	2002	70	0.3
8	Abul Hashem	Bipulasar	STW	2010	350	0.5
9	Shahjahan	Bipulasar	STW	1993	230	0.3
10	Md. Jahir Ahamed	Hasnabad	STW	2003	60	0.5
11	Md. Solaiman	Hasnabad	STW	2004	70	0.5
12	Md. Mujibul Hoque	Hasnabad	STW	2006	45	0.5
13	M A Wahab	Baisgaon	STW	2008	55	0.3
14	Saiful Islam	Baisgaon	STW	1998	65	0.3
15	Shafi Alam	Baisgaon	STW	2004	60	0.4
16	Abul Basher	Saraspur	STW	2003	70	0.5
17	Joynal Abedin	Saraspur	STW	1996	70	0.5
18	Md. Sohel	Saraspur	STW	1997	60	1.0
19	Jafar Miaji	Laxmanpur	STW	1998	80	1.0
20	Abdul Hanif	Laxmanpur	STW	1995	80	1.0
21	Sirazul Hoque	Laxmanpur	STW	2013	50	1.0
22	Sajeda Khatun	Jhalam Dakkhin	STW	1998	62	0.3
23	Rafiqul Islam	Jhalam Dakkhin	STW	2010	60	0.5
24	Shaymol	Jhalam Dakkhin	STW	2001	65	0.5
25	Mizanur Rahman	Jhalam Uttar	STW	2008	50	0.5
26	Mizanur Rahman	Jhalam Uttar	STW	2009	70	0.3
27	Sazzad Hossain	Jhalam Uttar	STW	2002	60	0.3
28	Sunil	Maisatua	STW	2004	60	0.5
29	Abdur Razzak	Maisatua	STW	2003	65	0.5
30	Delwar Hossain	Maisatua	STW	2005	70	0.5
31	Abdul Wahab	Uttar Hawla	STW	2011	60	1.0
32	Abul Hossain	Uttar Hawla	STW	2002	75	0.3
33	Masud Hossain	Uttar Hawla	STW	2013	70	0.3

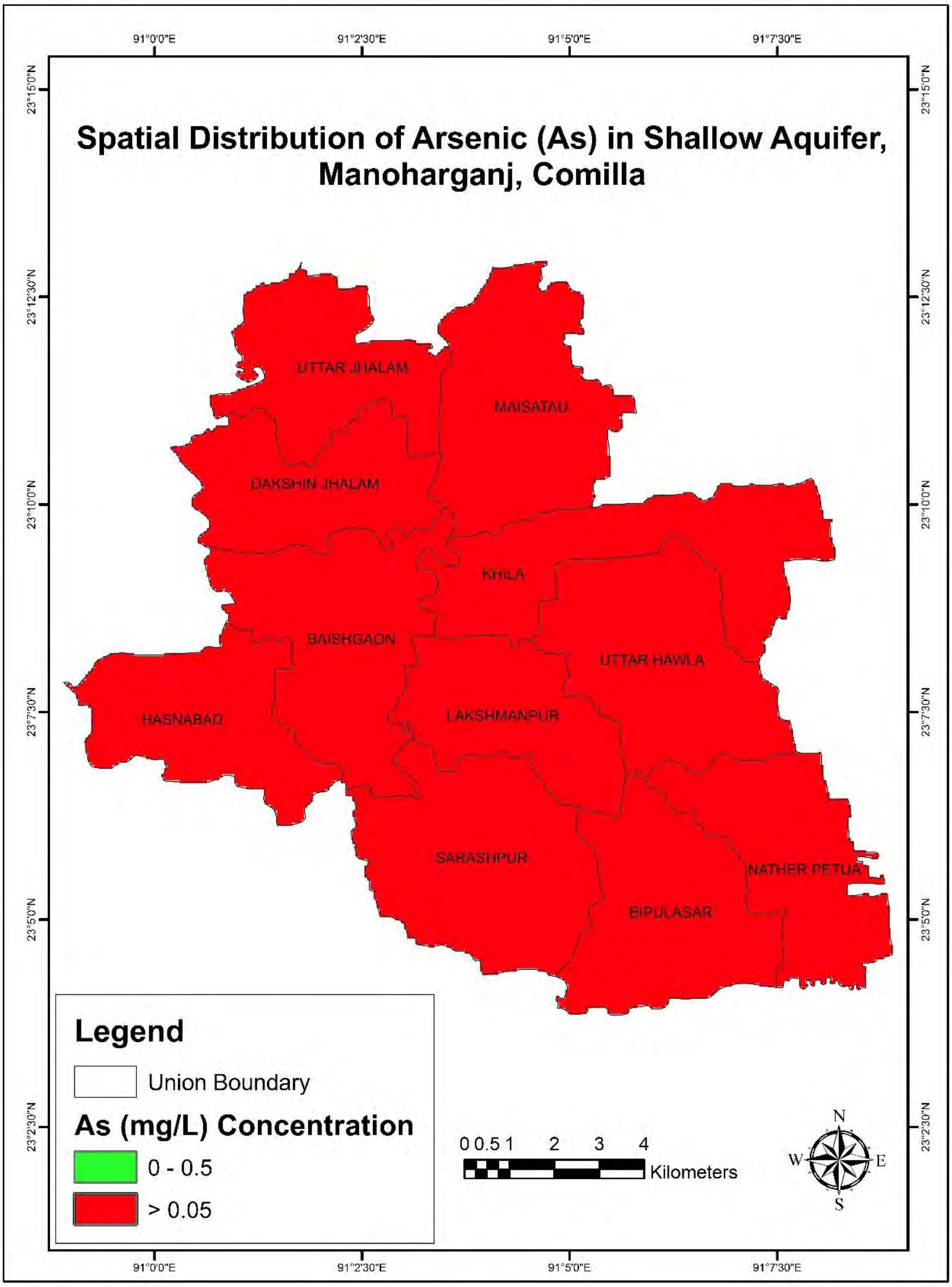


Figure 5-2: Arsenic Distribution Map in Shallow Aquifer

"I am a widow living with my three sons and a daughter. From 2003, we are isolated from the villagers as four (except younger son) of us are diagnosed as arsenicosis patients. Villagers said it is contagious and curst from God. My daughter could not get marry. My elder son's (was only earning member) situation is getting worse. Already we spent 3 lac taka for his treatment but no improvement. We are helpless now…"
Saira Banu, age 65, with her two sons, Hawra Village, Baishgaon Union, Manoharganj, 2012

"I was full of energy and work tirelessly in 8 members' family. From few years back I noticed development of odd spots on hands, legs and chest, aches and pains all over my body, and the occasional fever. Doctor diagnoses me as arsenicosis patient. Despite receiving hospital treatment and medication, the situation became worse day by day. I lost my ability to work and unable to continue treatment. I could barely walk now a days. I am dying… "
Shafiqur Rahman, 55, Baishgaon, Manoharganj, 2012.

"My husband died of serious arsenicosis that was turned into cancer. After his death I am going through huge financial crisis with my two children in last two years. I am working as day laborer to support family. Now I found some visible spot in my palm and chest. Still in our village we don't have any arsenic safe water to drink. I am scared, what will happen to my children if I also die…. please save us..".
Nasima Begum (35), from an extreme poor family of a remote village of Lakkhanpur union, Manoharganj, 2012

Rabiul Hossain, 21 years old studied upto grade 10, Arsenicosis Patient met in January 2012, died in March 2012. Mandargaon Pashchim para, Baishgaon Union.

Figure 5-3: Snap Shot of Arsenicosis Patients in Manoharganj

Figure 5-4: Few more arsenicosis patients in different unions of Manoharganj. a) Shahed Ali, 45; b) Amjad Ali, 50; c) Jalal Uddin, 48; d) Habib Mia, 55; e) Maimuna Begum, 45; f) Abdul Bashar, 40; g) Leg of Amjad Ali, 50.

5.3 Water Quality Problems in Deep Aquifer and Water Quality Mapping

5.3.1 Water Quality parameters test analysis and mapping

Due to severe arsenic problem in shallow tubewells, it was predicted that deep tubewells would be very straight forward solution. More than 500 deep tubewells were installed with support from government and other organizations by 2010. But it was found that many of these deep tubewells are not used by the people due to various water quality problems, such as; salinity, iron and smells. In this situation, out of project scope, using official network with EWAG, 117 water samples (representing all 11 unions) of deep tubewells (depth of 600ft -800ft) were randomly collected and tested in EWAG Lab, Switzerland. These water quality test data (see Annex 2) were used to understand the water quality problems in deep aquifer.

The summary of the test analysis has been provided in Table 5-2.

Table 5-2: Union wise level of contamination for different water quality parameters

Union	**# sample**	**% of contamination more than Bangladesh Standards**								
		Na (>200 mg/L)	K (>12 mg/L)	Ca (>75 mg/L)	Mg (>35 mg/L)	Fe (>1.0 mg/L)	Mn (>0.1 mg/L)	Cl (>600 mg/L)	Fl (>1.0 mg/L)	As (>0.05 mg/L)
Baishgaon	12	0	0	0	0	100	42	0	0	0
Bipulashar	6	17	0	17	17	100	17	17	0	0
Hasnabad	12	17	0	25	42	100	67	8	0	0
Jhalam Daxin	12	17	0	0	0	100	42	0	0	0
Jhalam Uttor	12	0	0	0	0	100	42	0	0	0
Khila	11	0	0	27	42	100	100	18	0	0
Laxmanpur	12	0	0	17	67	100	92	0	0	0
Maisatua	12	0	0	0	0	100	67	0	0	0
Natherpatua	7	86	29	86	86	100	100	86	0	0
Sorespur	12	0	0	8	8	100	67	0	0	0
Uttar Hawla	9	33	22	11	22	100	100	22	0	11
Total	**117**	**10**	**3**	**15**	**26**	**100**	**74**	**10**	**0**	**1**

From the Table 5-2, it has been found that all the unions are contaminated with iron and manganese more than Bangladesh Standards. In addition to iron and manganese, Bipulasar, Hasnabad, Khila, Natherpetua and Uttar hawla are also contaminated with chloride more than Bangladesh Standards.

Sodium (Na)

In the study area, 10% sample are found above Bangladesh standards of 200 mg/L for Sodium. From the spatial distribution map (Figure 5-5) it is clear that higher concentration occur mostly in the eastern and southern part of the study area and concentration above 200 mg/L are found in the wells of Khila, Uttar Hawla and Natherpatua Union. No firm conclusions can be drawn concerning the possible association between sodium in drinking-water and the occurrence of hypertension. Therefore, no health based guideline value is proposed by WHO in Drinking Water Guideline. However, concentrations in excess of 200 mg/L (Bangladesh Standard) may give rise to unacceptable taste.

Potassium (K)

Potassium is less abundant in the groundwater of the study area and its concentration in the groundwater ranges from 2.01 mg/L to 12 mg/L (Bangladesh Standards) mostly. No health based guideline value is proposed by WHO in Drinking Water Guideline. Concentration greater than 12 mg/L occurred in the eastern and southern part of the study area covering Khila, Uttar Hawla and Natherpatua Union (Figure 5-6).

Calcium (Ca)

Calcium concentration of shallow groundwater in the study area is relatively high ranging from 12 mg/L to 275 mg/L. 15% sample are found above Bangladesh standards of 75 mg/L for Calcium. Distribution map of Ca (Figure 5-7) shows that concentration greater than 75 mg/L occurred at the center and south eastern portion of the study area.

Magnesium (Mg)

Magnesium concentration in groundwater of the study area ranges from 9 to 204 mg/L and 26% samples are found above Bangladesh standards of 35 mg/L for Magnesium. The spatial distribution of magnesium (Figure 5-8) in the study area shows similar pattern of calcium where higher concentration occur at the central and south eastern part of the study area.

Iron (Fe)

In the present study iron was measured as total iron. Iron concentration in groundwater of the study area ranges from 1.1 mg/L to 25.00 mg/L. 100% samples are found above Bangladesh standards of 1.0 mg/L for Iron. Spatial distribution pattern shows that the concentration of Iron (Figure 5-9) increases towards the eastern and south eastern and westernmost portion of the area.

Manganese (Mn)

Total Manganese in the study area range from 0.021 mg/L to 1.013 mg/L. 74% samples are found above Bangladesh standards of 0.1 mg/L and 9% are found above WHO guideline value 0.4 mg/L for Mn. There is a considerable concern in Bangladesh over the concentration of Mn (WHO guideline value is 0.4 mg/L) in groundwater, because of its known toxic effects to human. The spatial distribution of Manganese in the study area (Figure 5-10) shows that eastern and westernmost portion of the study area including Khila, Uttar Hawla and Hasnabad union have Mn value higher than 0.4 mg/L.

Chloride (Cl):

Chloride concentration in groundwater of the study area ranges from 0 mg/L to 3335 mg/L. 10% samples are found above Bangladesh standards of 600 mg/L for Chloride. Distribution map (Figure 5-11) shows that eastern, south eastern, central and western portion of the study area show higher values of chloride concentration (>250mg/L) whereas northern and south western portion depict lower chloride concentration. Portions with higher chloride concentration include Hasnabad, Khila, Lakshmanpur, Uttar Hawla, Bipulashar and Natherpetua Unions.

Arsenic

Only one samples is found above Bangladesh standards of 0.05 mg/L for arsenic in deep aquifer in Uttar Hawla union which is 0.056 mg/L. Spatial Distribution map shown in Figure 5-12.

pH (Hydrogen ion concentration)

pH values of the groundwater range from 6.05 to 6.95 with the median value of 6.64 indicating slightly acidic to nearly neutral groundwater condition. The spatial distribution pattern of pH (Figure 5-13) shows that nearly neutral values (6.5-7.0) prevail in most of the areas. However, a slightly acidic condition prevails in the central and southern part of the study area.

Fluoride

Fluoride concentration in groundwater of the study area ranges from 0.09 mg/L to 0.82 mg/L. No samples are found above Bangladesh standards of 1.0 mg/L for Fluoride.

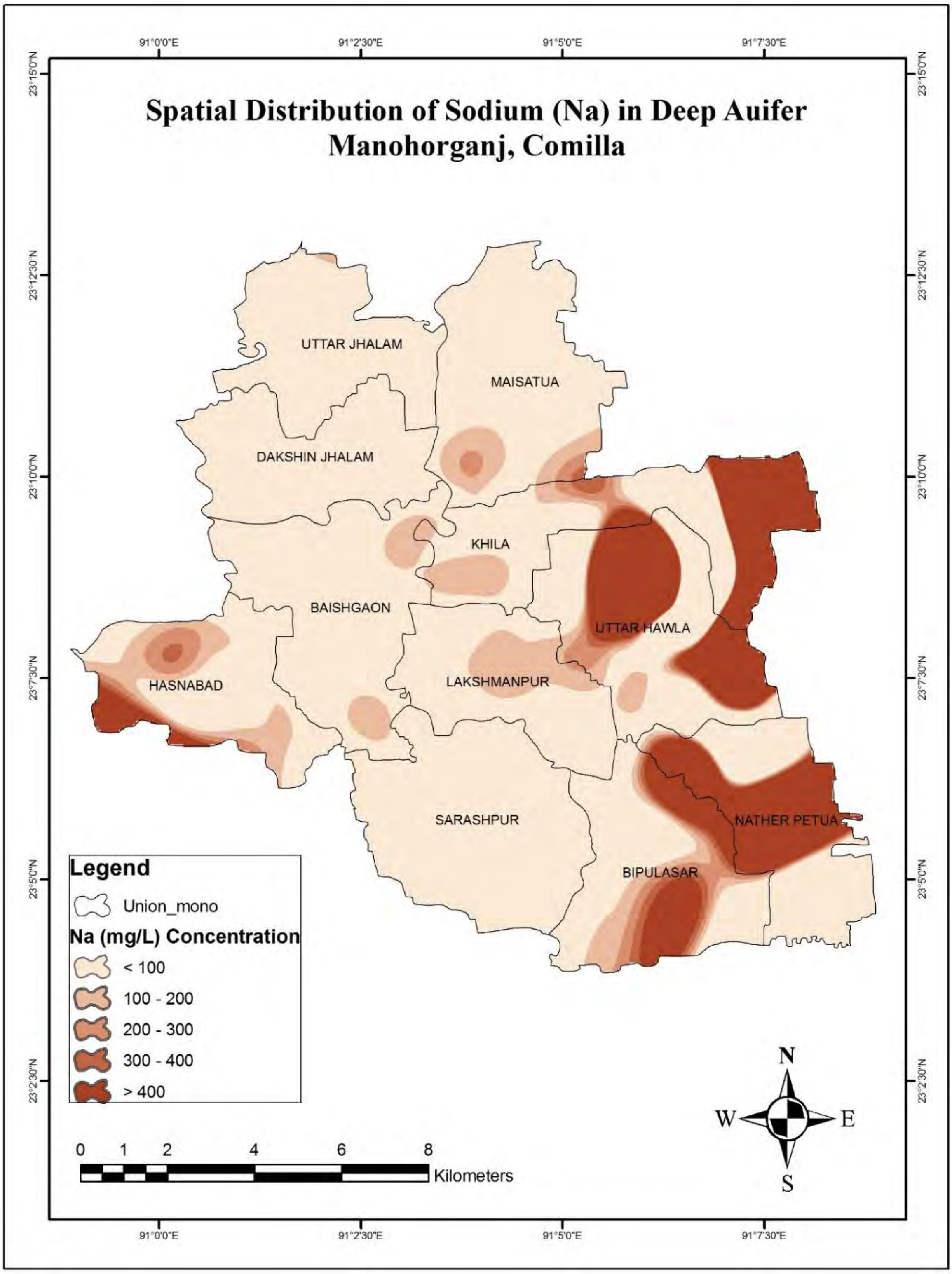


Figure 5-5: Spatial Distribution of Sodium (Na) in deep aquifer

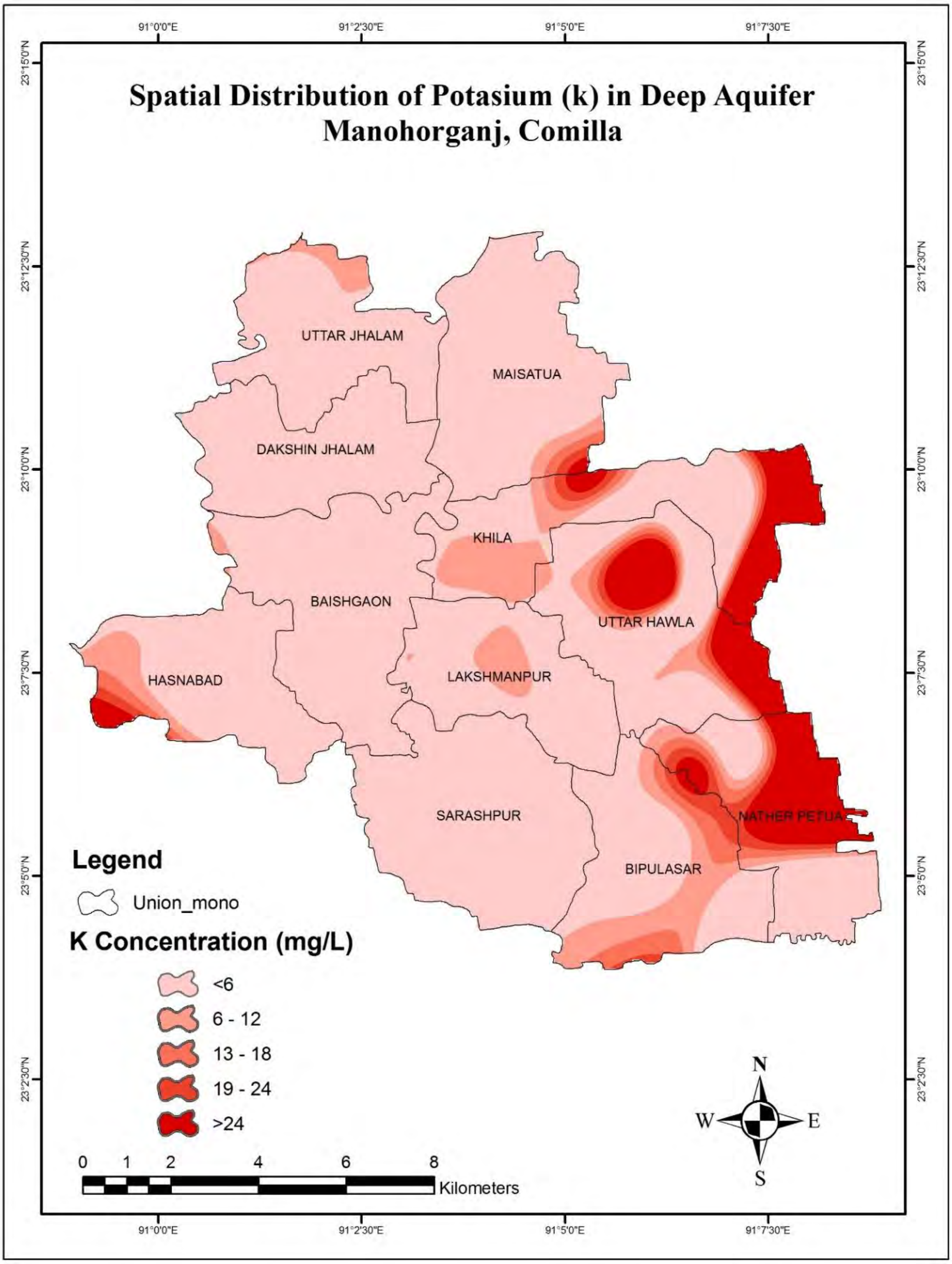


Figure 5-6: Spatial Distribution of Potassium (K) in deep aquifer

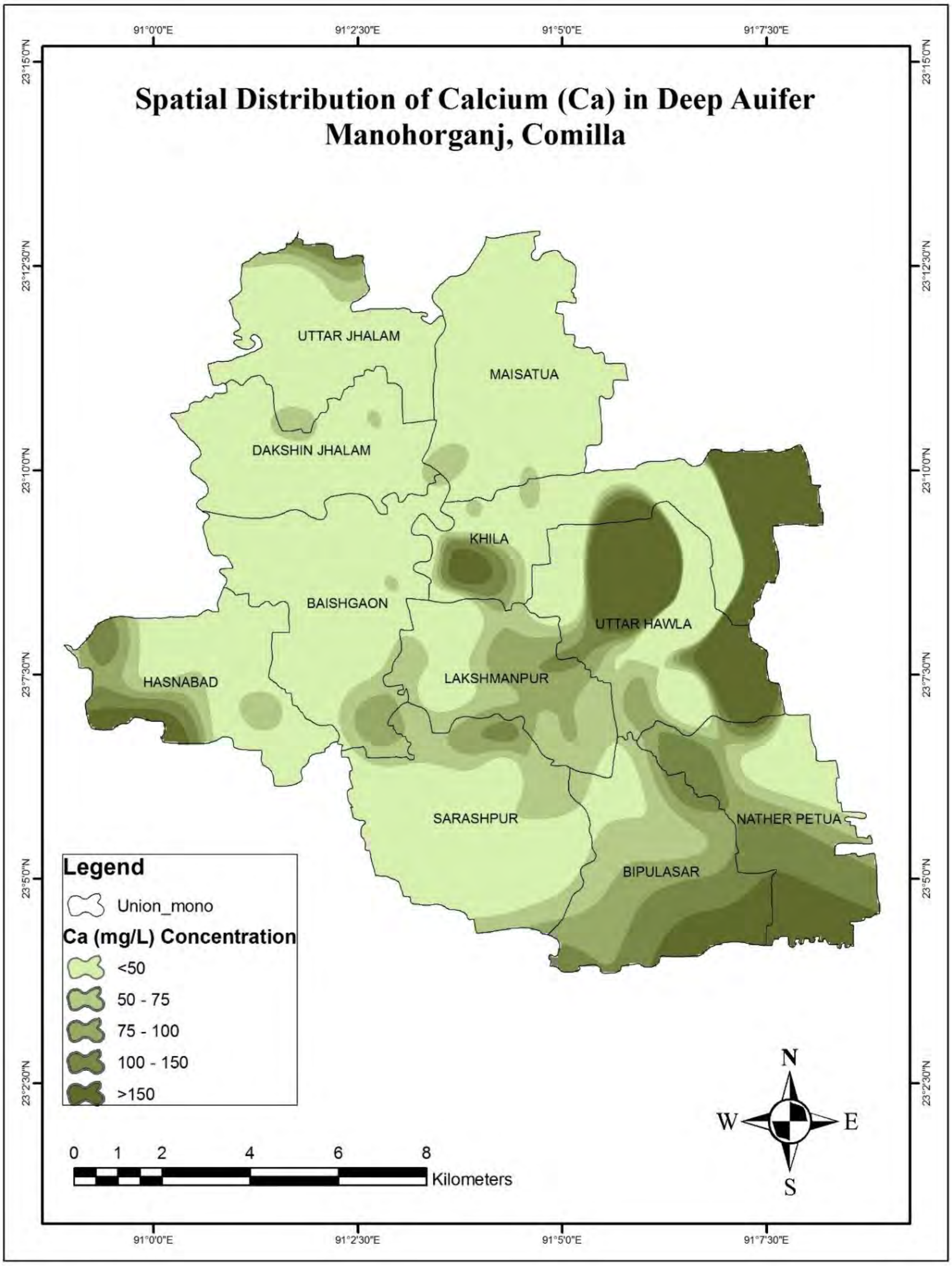


Figure 5-7: Spatial Distribution of Calcium (Ca) in deep aquifer

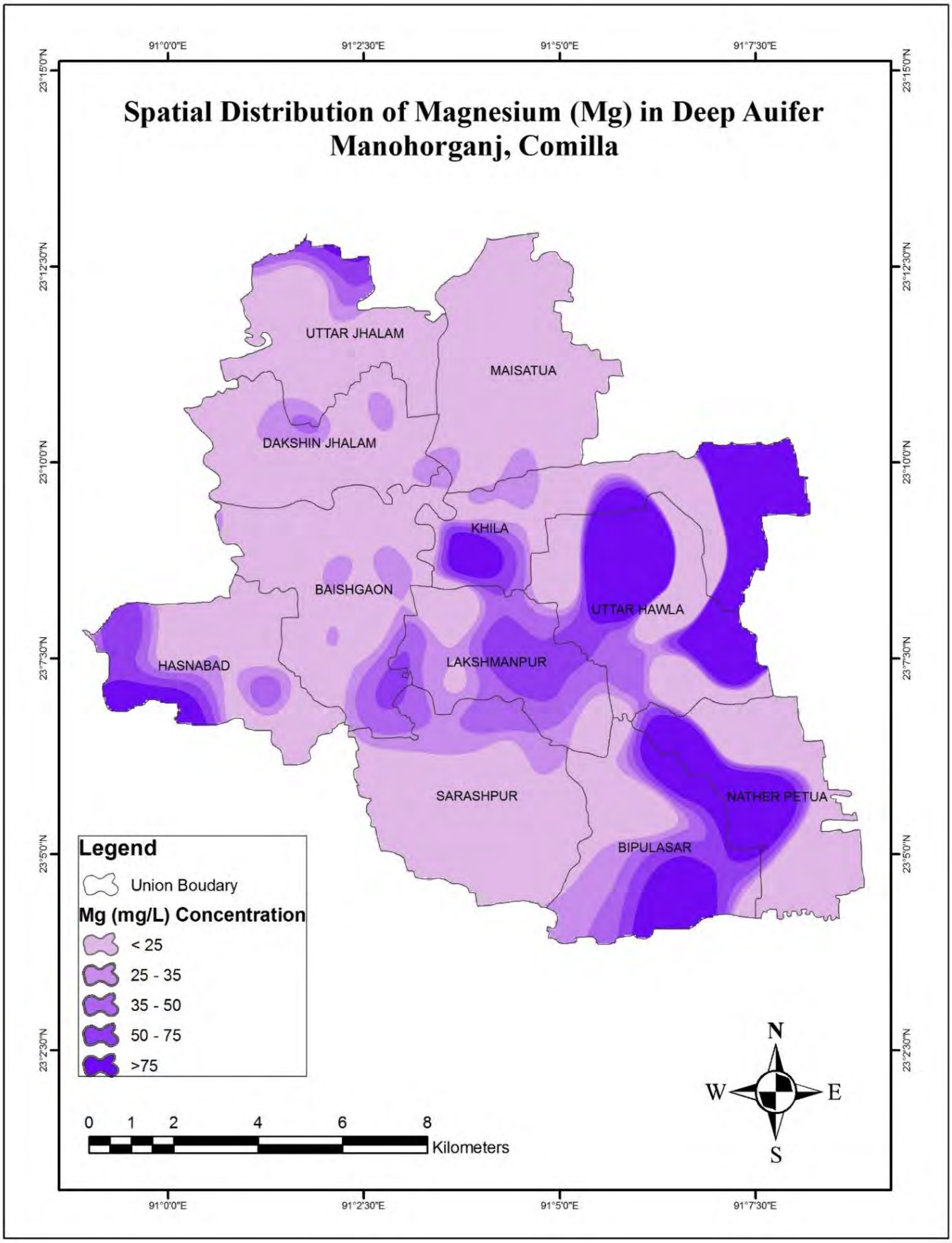


Figure 5-8: Spatial Distribution of Magnesium (Mg) in deep aquifer

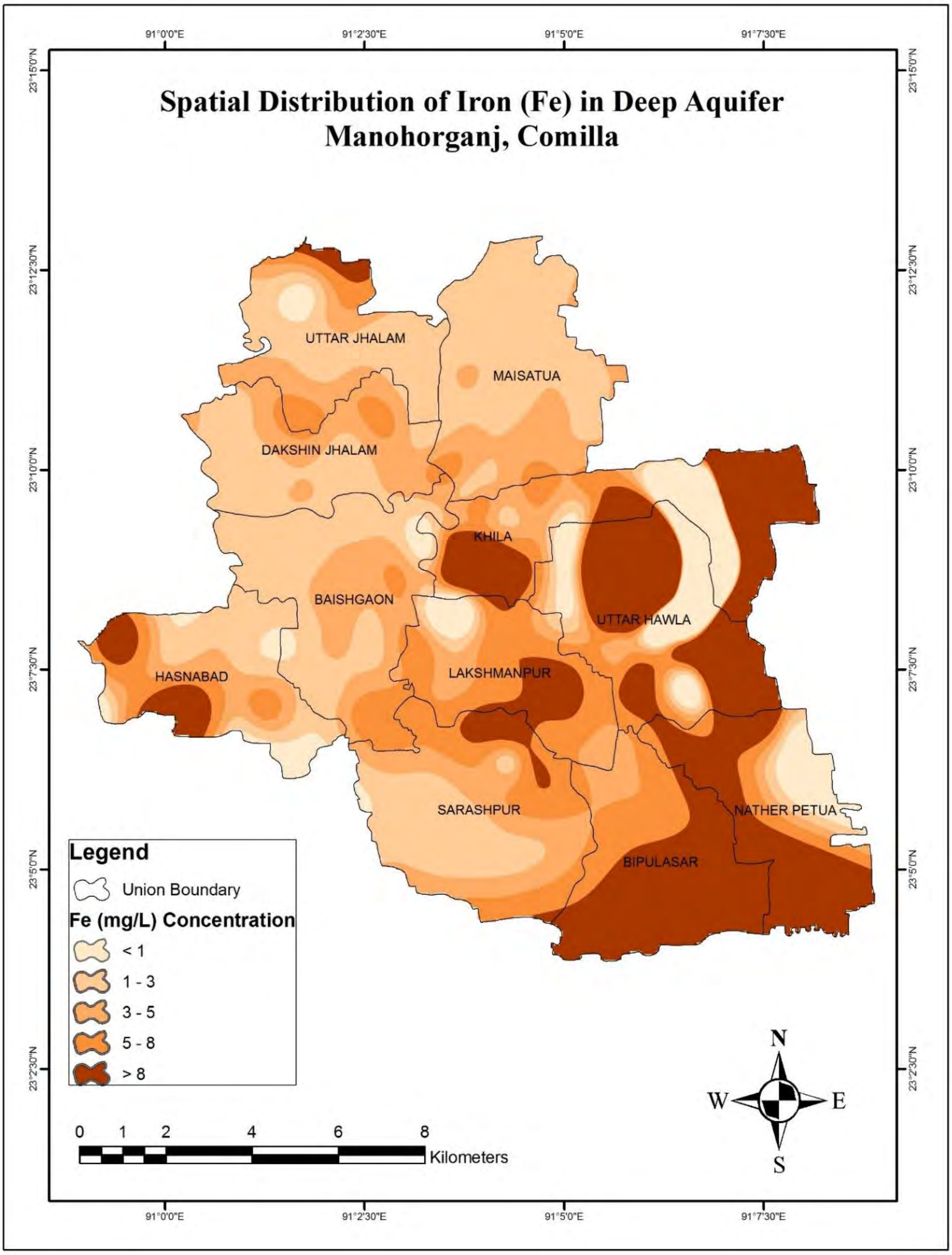


Figure 5-9: Spatial Distribution of Iron (Fe) in deep aquifer

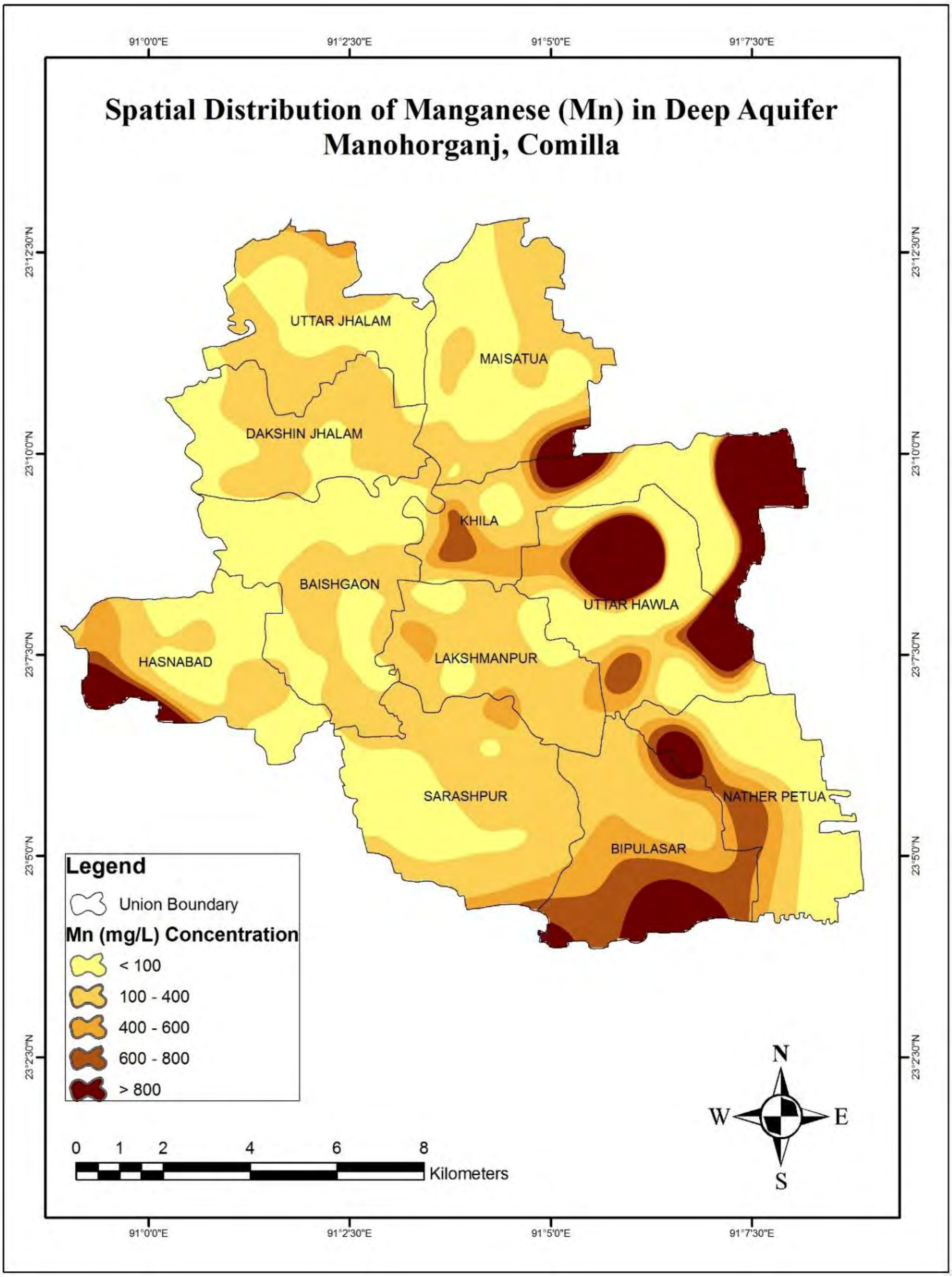


Figure 5-10: Spatial Distribution of Manganese (Mn) in deep aquifer

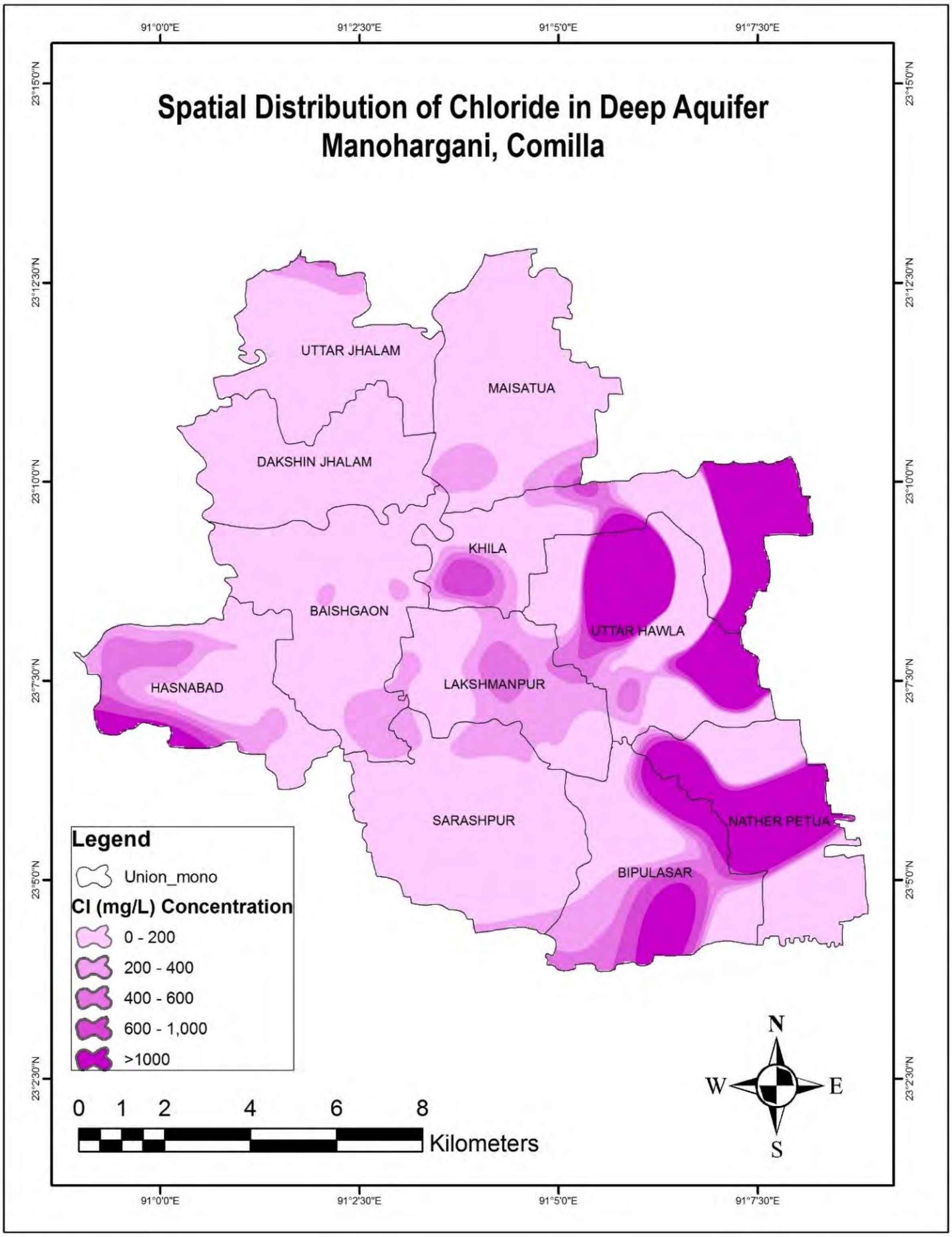


Figure 5-11: Spatial Distribution of Chloride (Cl) in deep aquifer

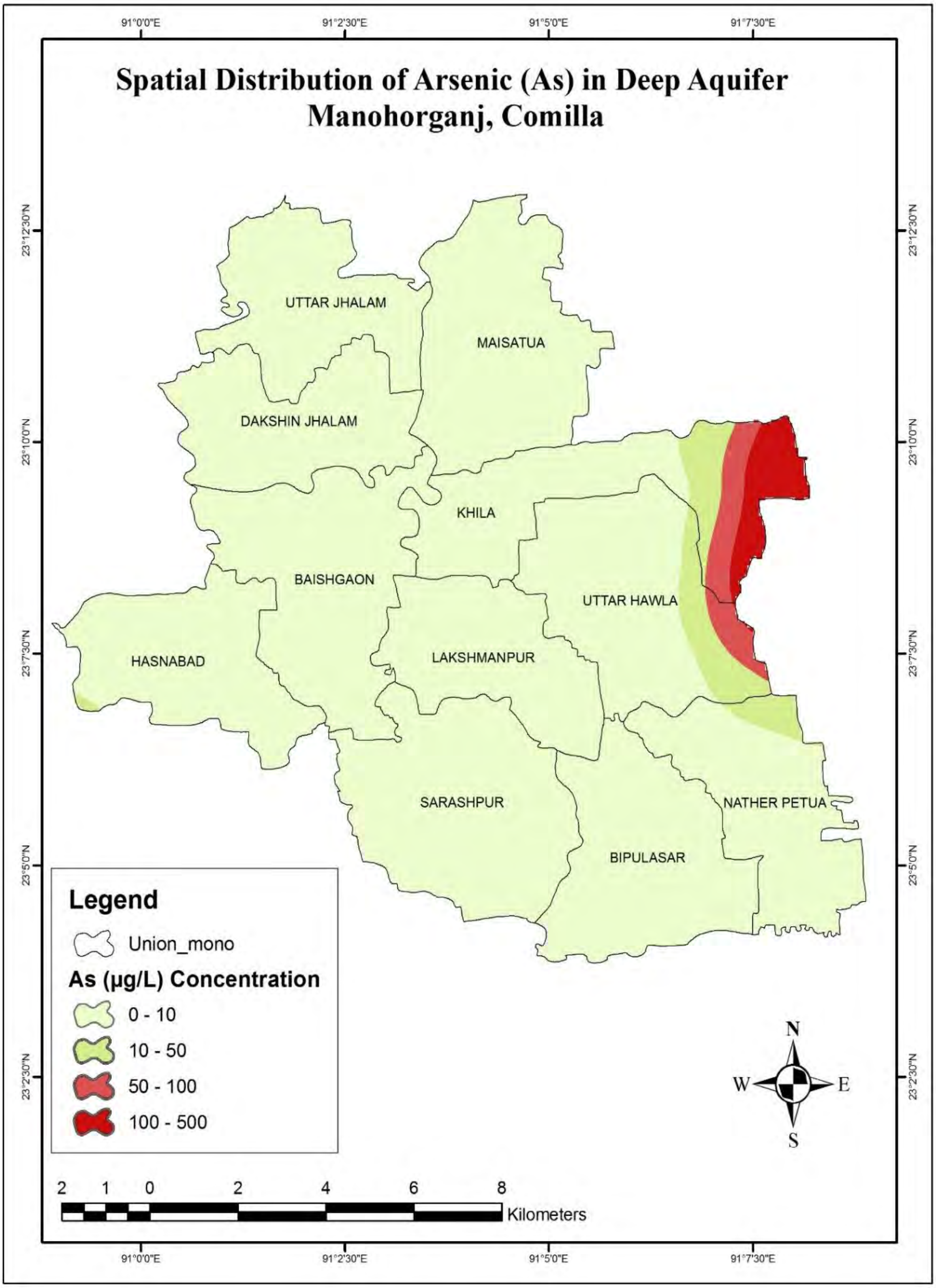


Figure 5-12: Spatial Distribution of Arsenic (As) in deep aquifer

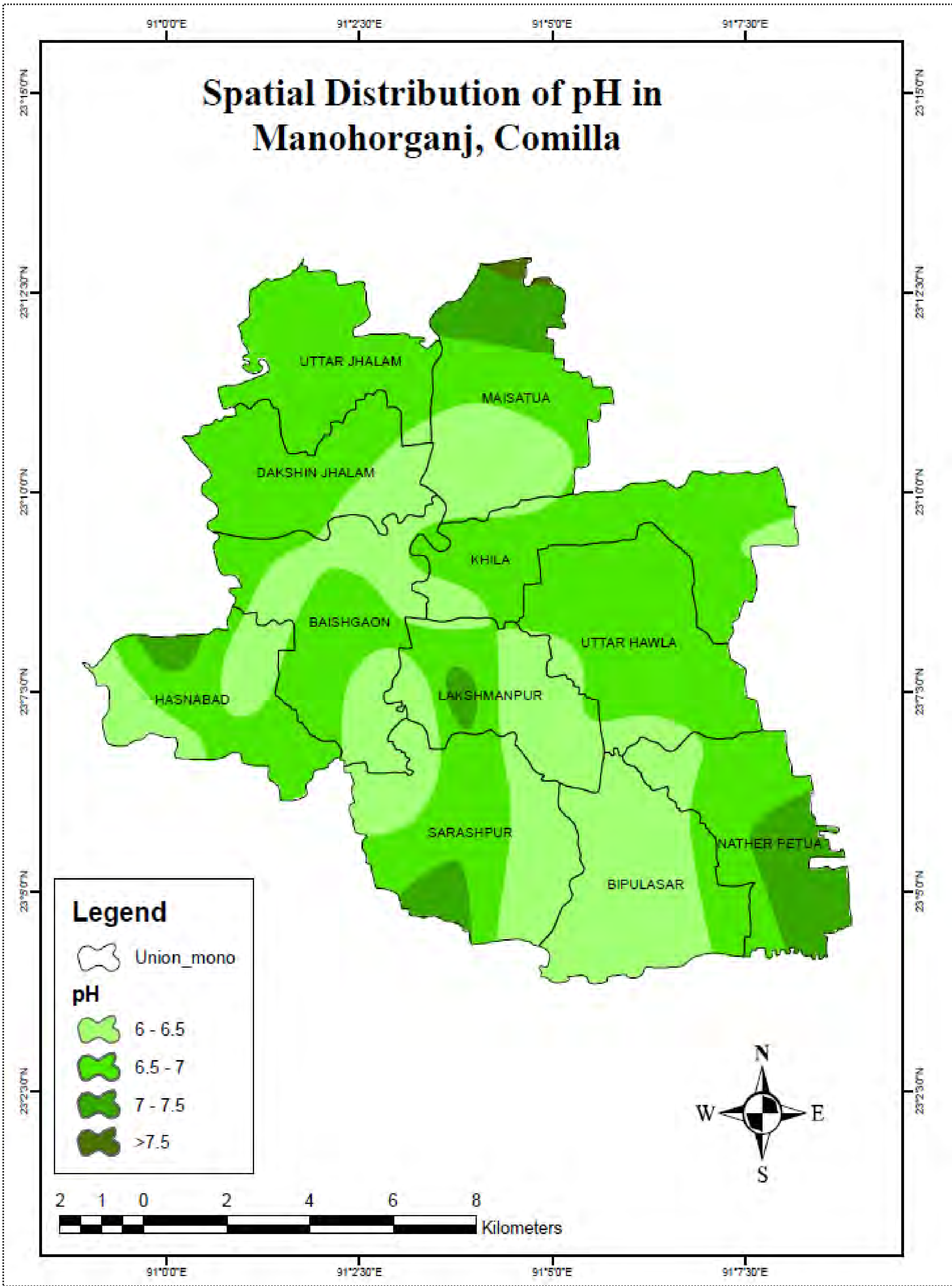


Figure 5-13: Spatial Distribution of pH in deep aquifer

5.3.2 Combining major water quality problems and mapping

Combining major water quality problems in Manohorganj with respect to Bangladesh Standards, it has been found that eastern, south eastern and central portion of the study area are more vulnerable to water quality problems. Using the same water quality data of 117 wells, summary provided in Table 5-2 (detailed in Annex-2), it has been found that all the unions are contaminated with iron and manganese more than Bangladesh Standards and only Bipulasar, Hasnabad, Khila, Natherpetua and Uttar hawla are contaminated with chloride more than Bangladesh Standards.

Different water quality data has been combined to identify the location of most challenging areas where traditional technologies will not be appropriate to provide safe water. The spatial distribution pattern for Na and K shows eastern and south eastern portion are higher than Bangladesh Standards (Figure 5-14). Similarly Ca and Mg shows eastern, south eastern and central portion are higher than Bangladesh Standards (Figure 5-15). The spatial distribution pattern for Fe and Mn shows that almost 100% of the study area are higher than Bangladesh Standards (Figure 5-16). However, when WHO guideline for Mn has been considered, the situation is different (Figure 5-17). As the iron, manganese and chloride are the major water quality problem, the combined map of iron, chloride and manganese has been produced. Here for iron and chloride, Bangladesh standards has been considered and for manganese WHO guideline value has been considered (Figure 5-18). From this combined map it has been found that mostly eastern and south eastern part of the study area (Khila, Uttar Hawla, Natherpetua, Bipulashar union) and small portion of west part (Hasnabad union) are more vulnerable to water quality problems of iron, manganese and chloride in deep aquifer. To provide safe water in these unions need further careful technology selection or pilot new technologies.

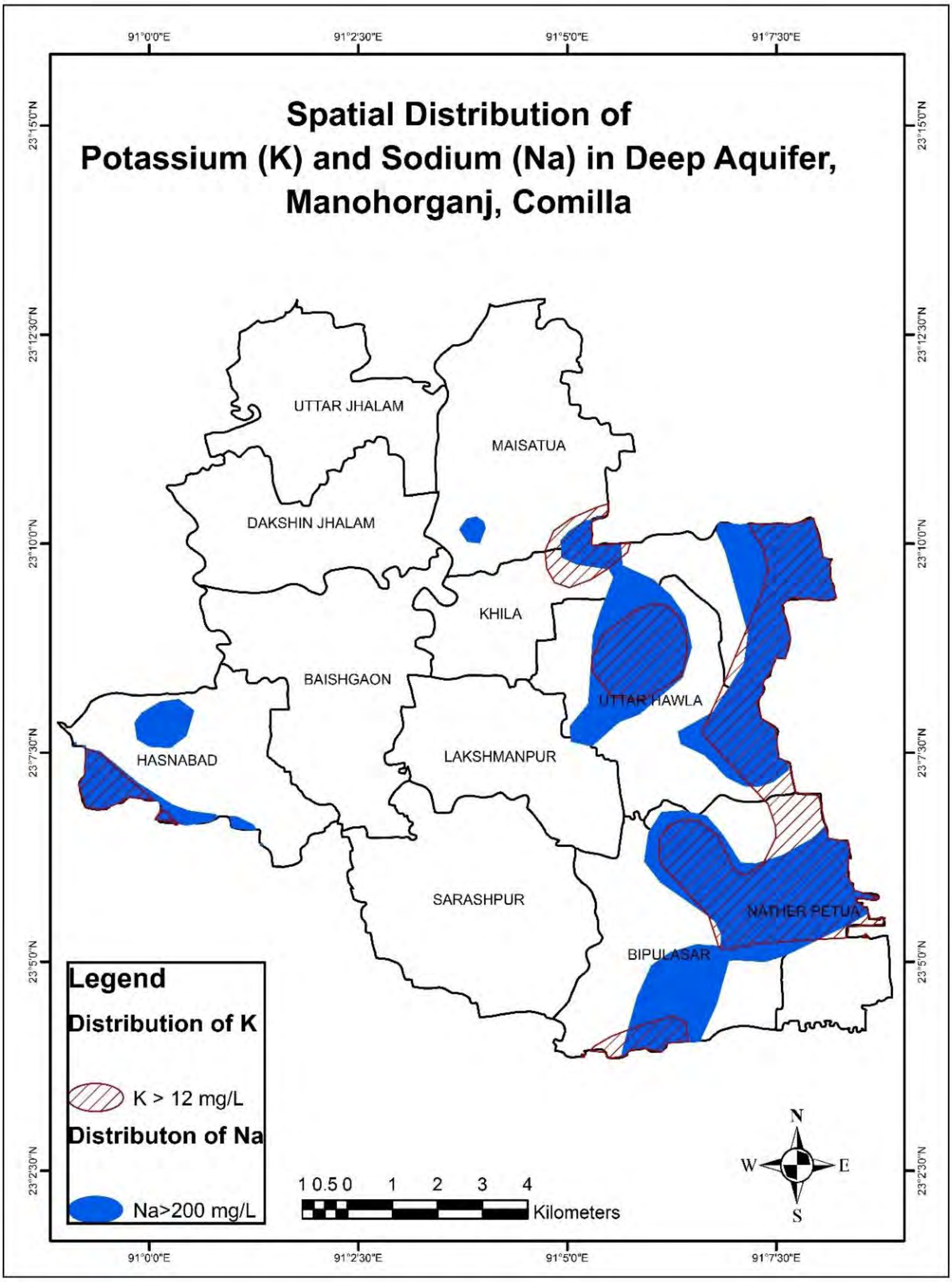


Figure 5-14: Combined Spatial Distribution of Sodium (Na) and Potassium (K) in deep aquifer

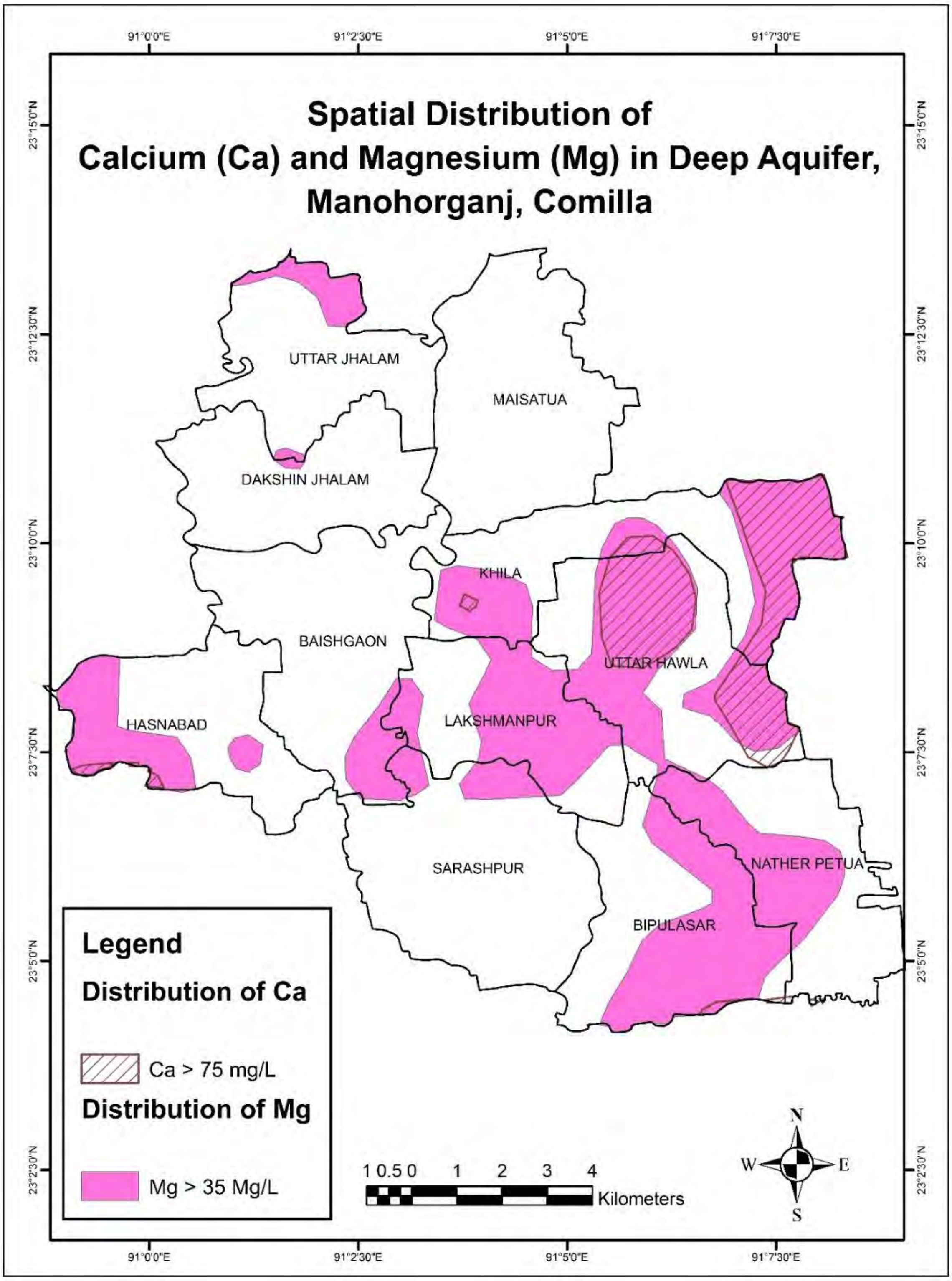


Figure 5-15: Combined Spatial Distribution of Calcium (Ca) and Magnesium (Mg) in deep aquifer

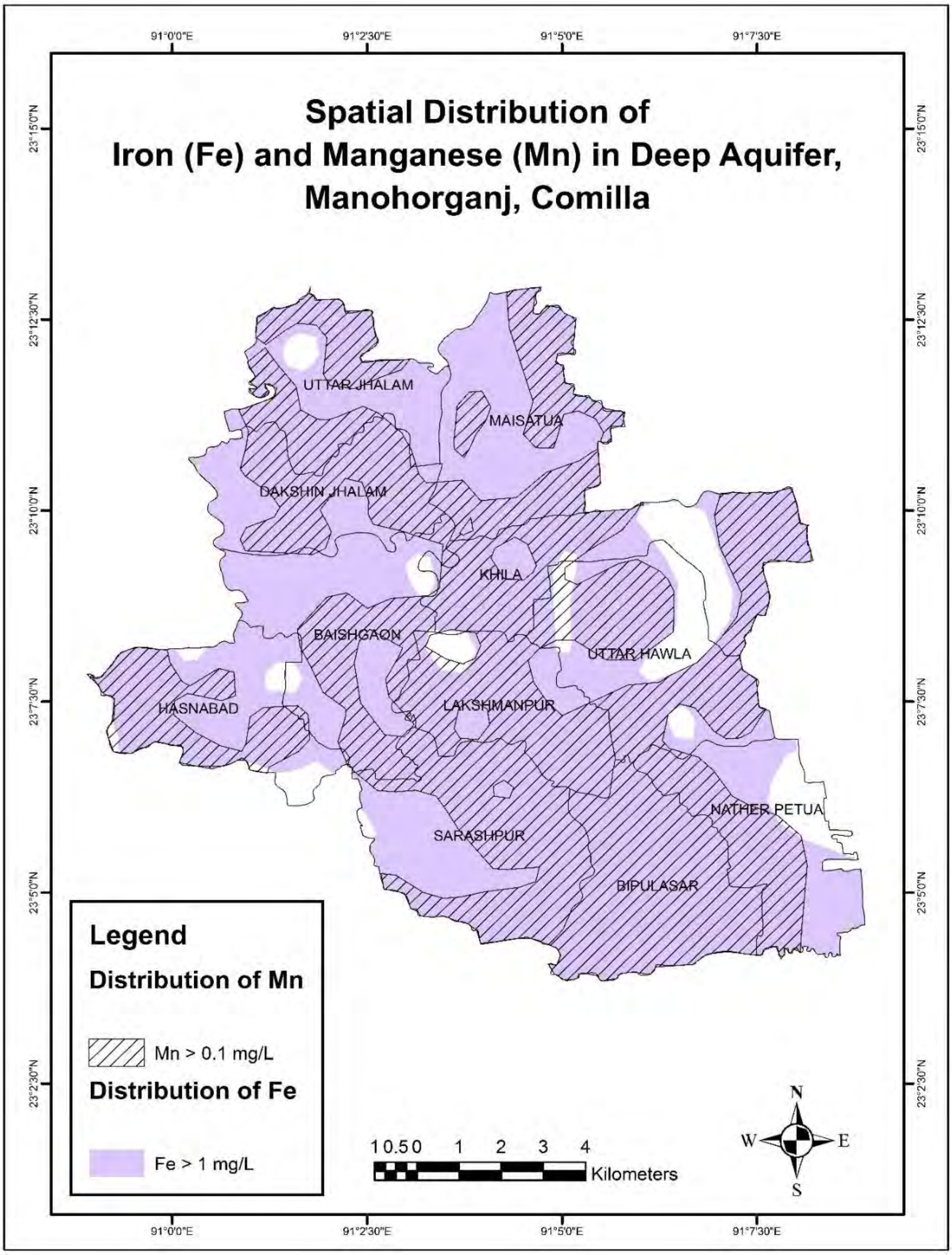


Figure 5-16: Combined Spatial Distribution of Iron (Fe) and Manganese (Mn) more than BD Standards in deep aquifer

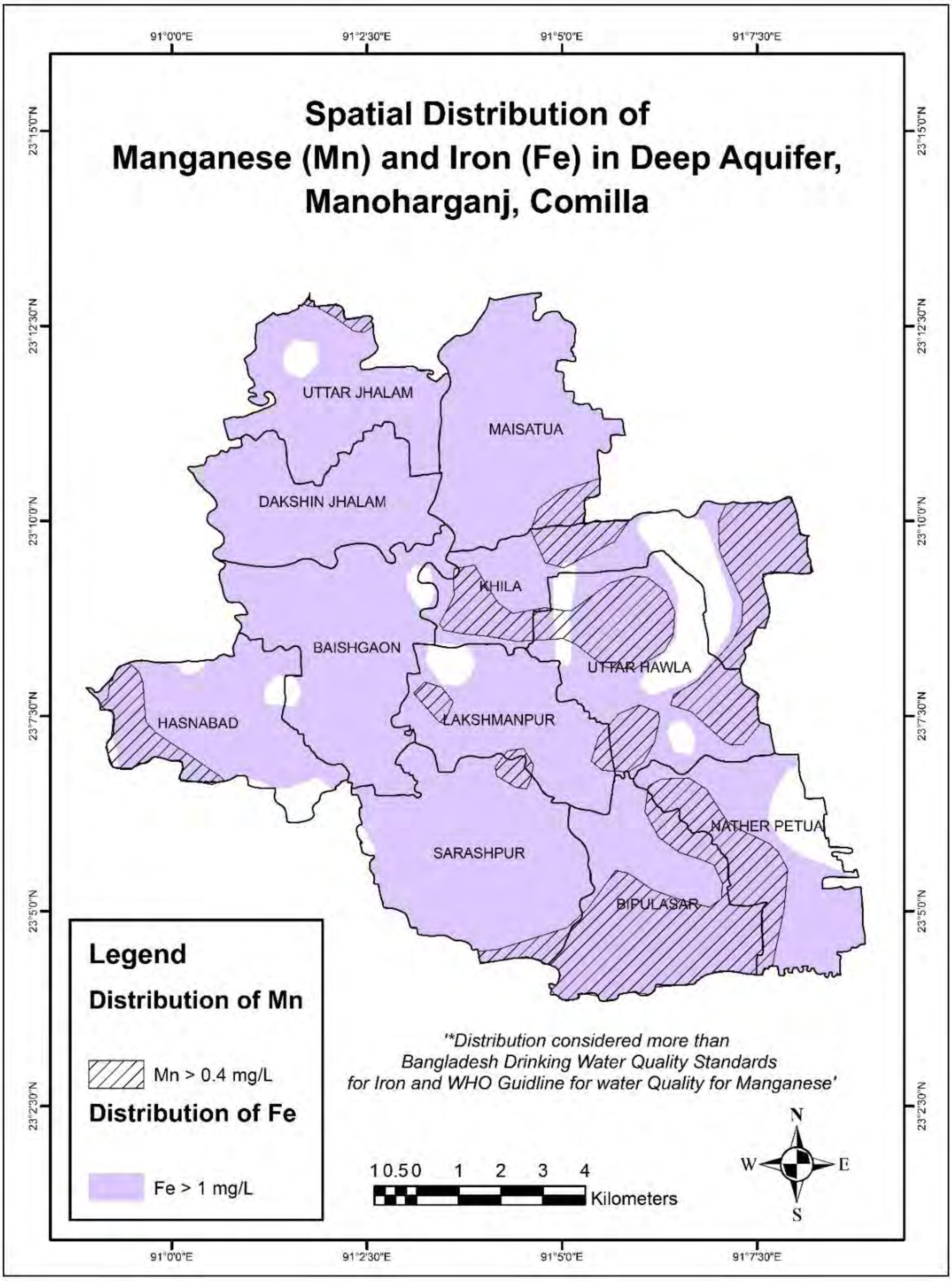


Figure 5-17: Combined Spatial Distribution of Iron (Fe) and Manganese (Mn) more than BD Standards for Fe and WHO guideline value for Mn in deep aquifer

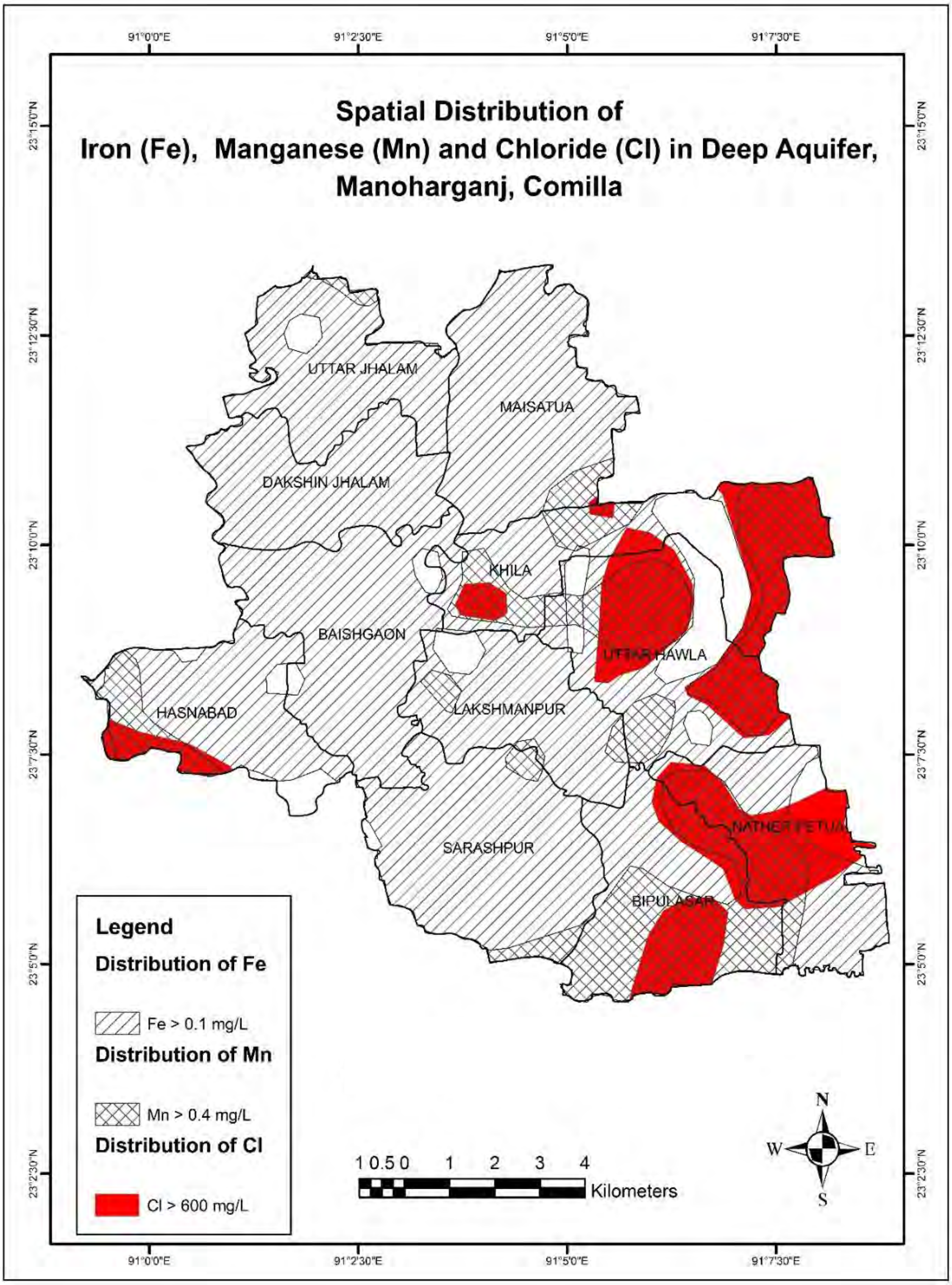


Figure 5-18: Combined Spatial Distribution of Iron (Fe) and Manganese (Mn) and Chloride (Cl) following BD Standards for Fe and Cl and WHO guideline value for Mn, in deep aquifer

5.4 Targeting Fresh Aquifer

This section mainly deals with the evaluation of the aquifer conditions of the study area in terms of regional hydrogeological settings, aquifer system and groundwater levels.

In order to provide safe drinking water in the arsenic affected Manohorganj Upazila, deep tube wells is found most suitable and sustainable option. But the deep tube wells not always provide fresh water, especially in the south and south eastern and central region of Bangladesh. It often produces water with higher salinity, increased hardness and greater concentrations of Fe and Mn compared to water from shallow tube wells and in some cases high salinity severely affects the quality of deep groundwater.

One of the purposes of this research was therefore to find out whether it is possible to identify and target fresh aquifers in the study area before installing the deep tube wells.

5.4.1 Hydrostratigraphy and aquifer system

From the 55 borelog analysis it has been found that upper 50-80 feet portion of the study area is mainly dark grey clay and silty clay. Beneath this layer, a continuous fine to medium sandy layer is present up to 300- 400 feet depth. Based on the bore logs, two hydrostratigraphic cross section (Figure 5-19) has been constructed to picture the aquifers in the subsurface. Section AA' shows the NS hydrostratigraphic cross section which show the variation of aquifer geometry in NS direction. Section BB' shows the West-East hydrostratigraphic cross section which depict the variation of aquifer geometry in the WE direction.

From the NS section, it is evident that two distinct deep aquifer (aquifer-2 and aquifer-3) present in the southern to central portion of the study area whereas in the northern portion, there is no aquifer-3 up to the depth of 800 feet. In addition, there are pronounced variation in the occurrence and distribution of the aquitards, particularly the one separating the aquifer -1 and aquifer-2. Thickness of the aquitard-2 is more or less same in the middle portion of north south direction except at the end of northern part where it changed dramatically and becomes thinner and deeper created a "V" shaped region.

Aquitard-3 either absent or present at a greater depth in the north whereas it occurs at a varying depth in the south.

From the WE section in the central part of the area it is revealed that there are two major aquifers present throughout the area. Aquitard-1 mainly consists of silt and silty clay works as a vadose zone across the area. Aquitard-2, which separates the aquifer-1 and aquifer-2 presents between 300-400 feet depth range except in the end of the western part of the area. Thickness of the aquitard-2 is more or less same from the middle portion to eastern direction and becomes deeper and thinner at the north. Presence of another thin clay layer around 500-650 feet depth range in the central and eastern portion of the study area act as aquitard -3 which separates aquifer-2 from aquifer-3.

Aquifer models

Figure 5-20 presents the variation in the depth and thickness of the aquifers and aquitards of the study area. The aquitards thicknesses vary widely in the study area and thicken towards south. The number of aquifer is less in the northern part whereas there are up to three aquifers in the southern part. The second aquifer varies widely in thickness throughout the study area thickening towards north.

Hydrostratigraphic model of the study area reveals a six-layer hydrostratigraphy for the Manohorganj Upazila (Figure 5-21 and Figure 5-22). The top clay-silt aquitard layer act as a vadose zone throughout the area with an average thickness of about 50- 80 feet. The shallow aquifer (aquifer- 1) is very thick with an average thickness of 250 feet. The thickness of the second aquitard varies from 30 to 80 feet whereas the depth to the base of the second aquitard varies from 350-600 feet. The first deep aquifer (aquifer-2) becomes significantly thicker towards the west and north whereas the second deep aquifer (aquifer-3) occurs mainly in the eastern and southern part of Manohorganj. Table 5-3 gives an overview of the hydrostratigraphy of the study area.

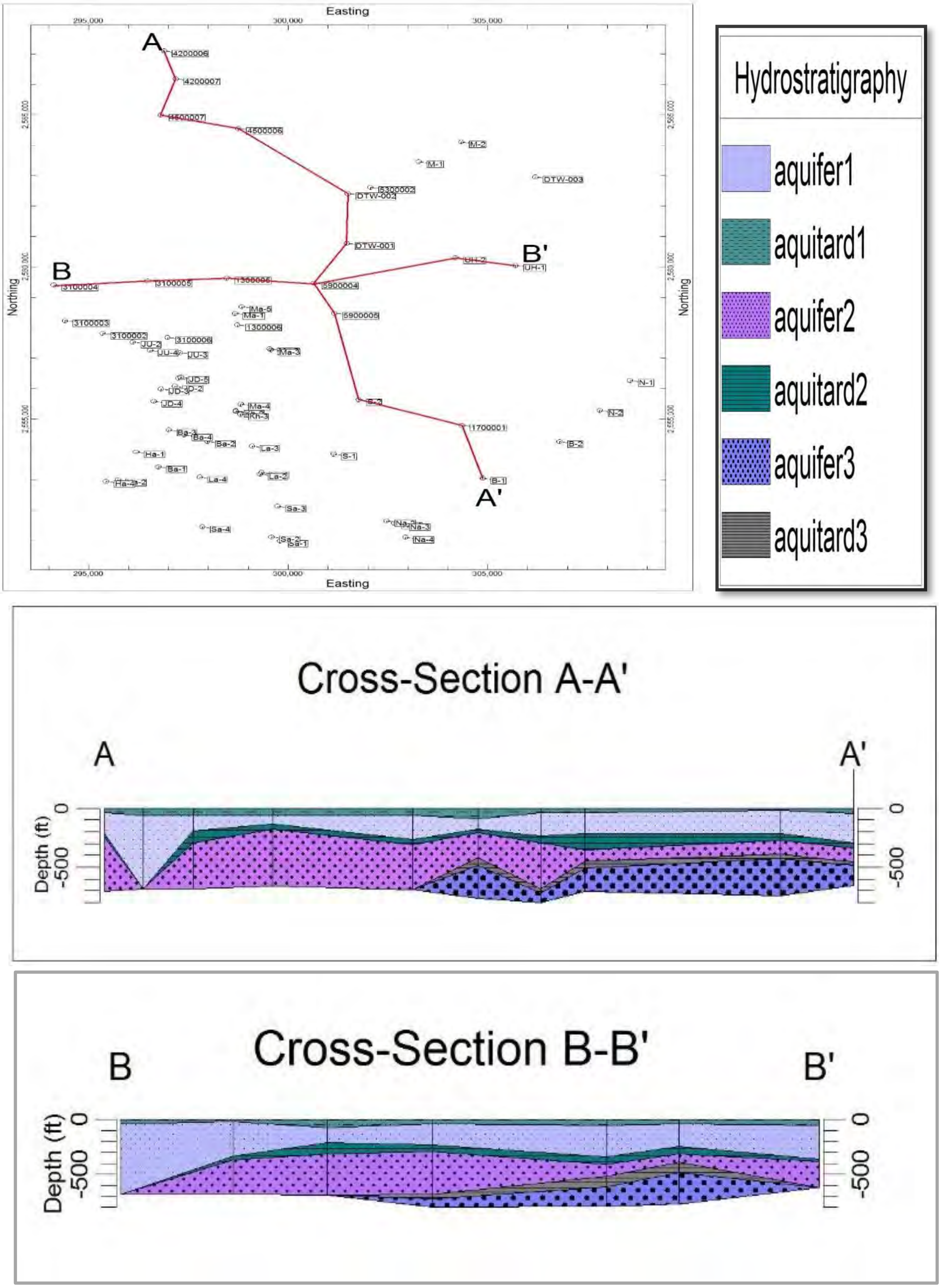


Figure 5-19: Hydrostratigraphic cross section line (map) and NS hydrostratigraphic cross section along line AA' and WE hydrostratigraphic cross section along line BB' in the study area.

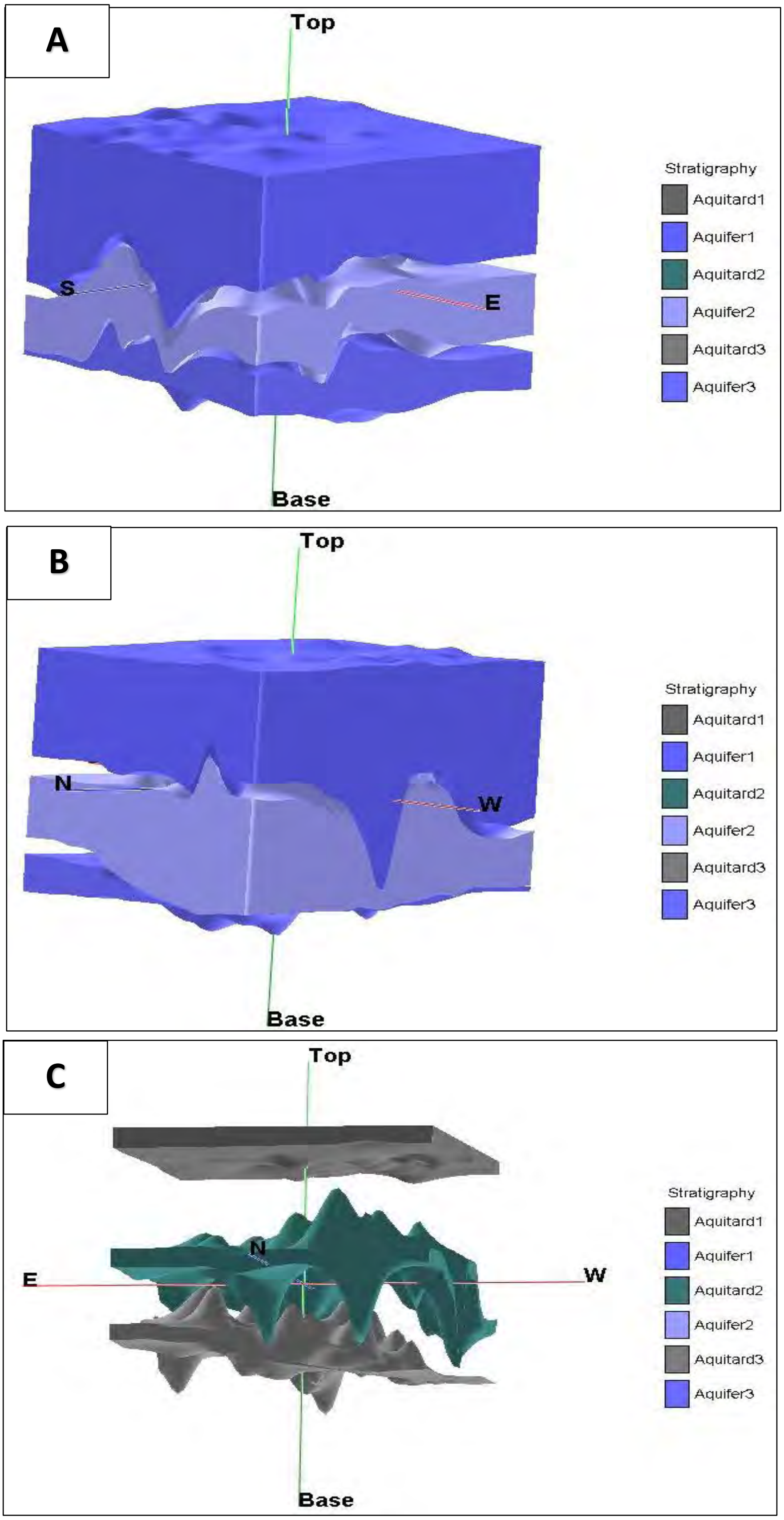
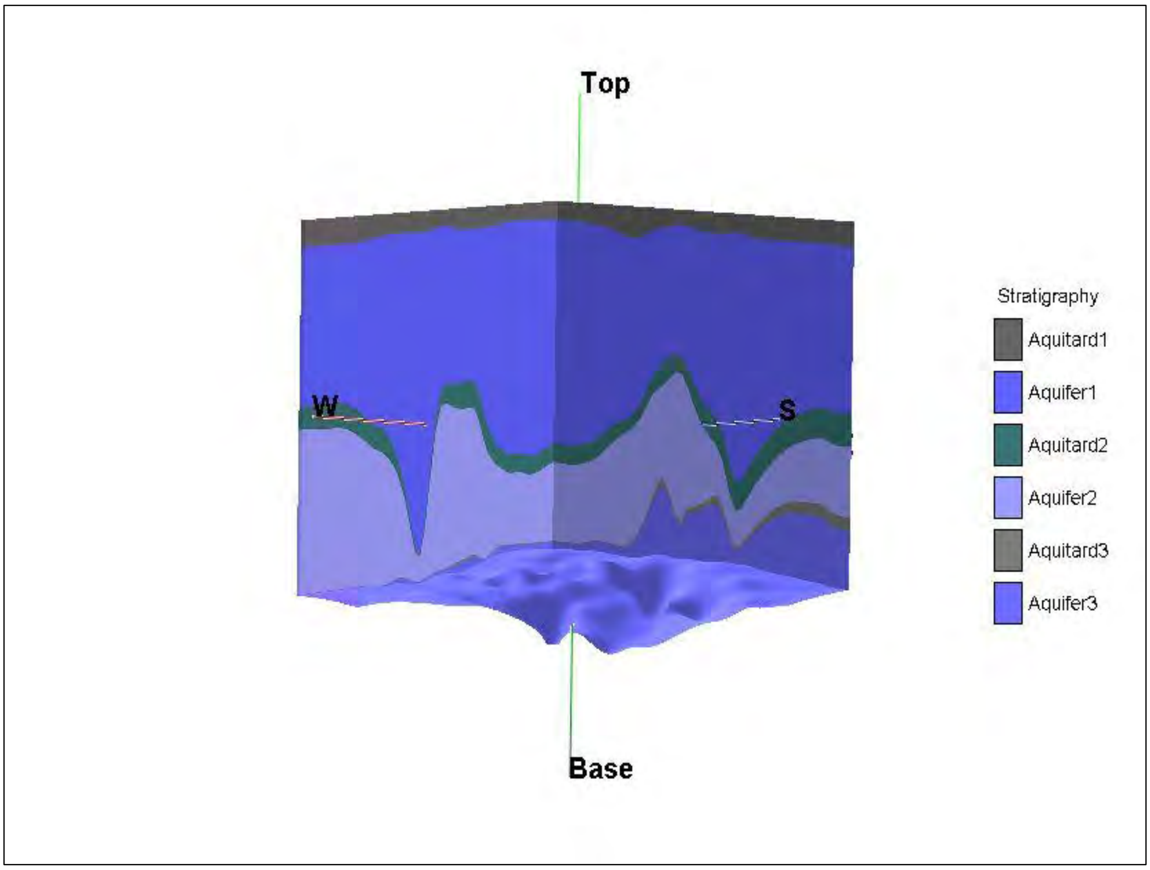


Figure 5-20: Model of aquifers in A) South –East direction and in B) North- West direction and C) model of Aquitard.



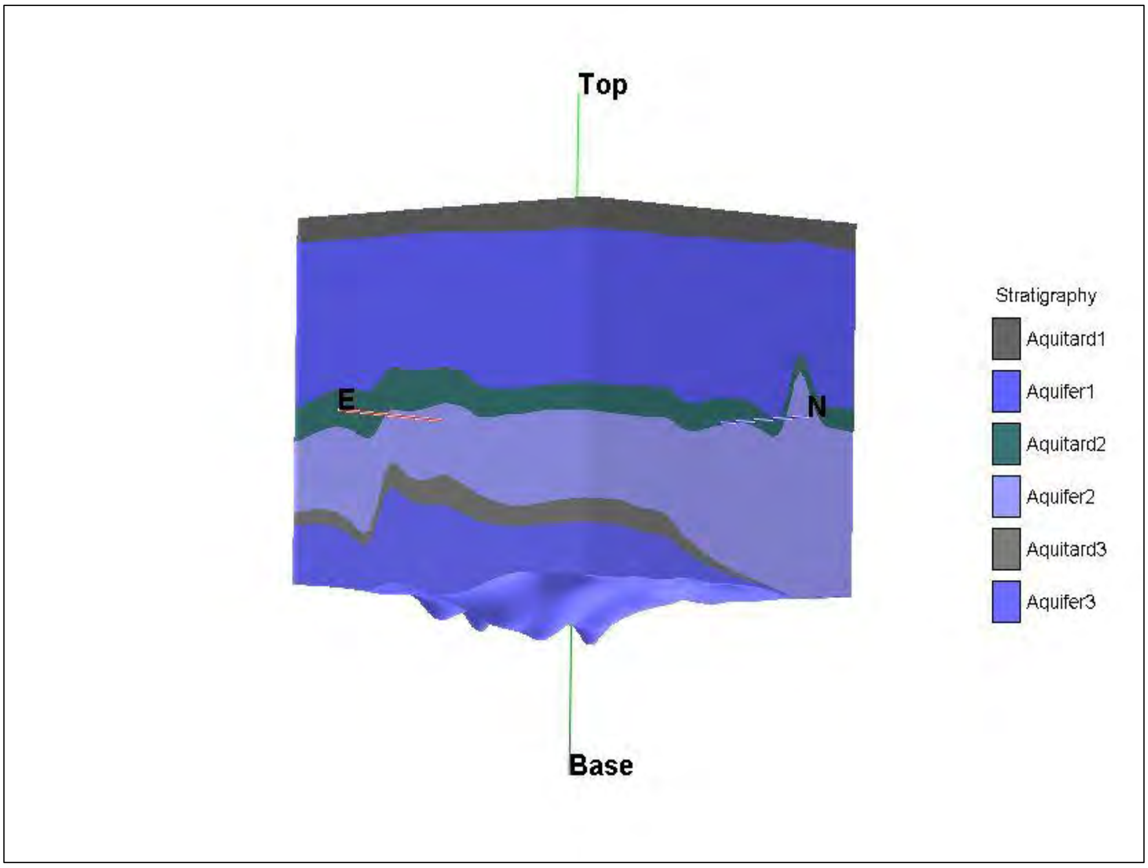
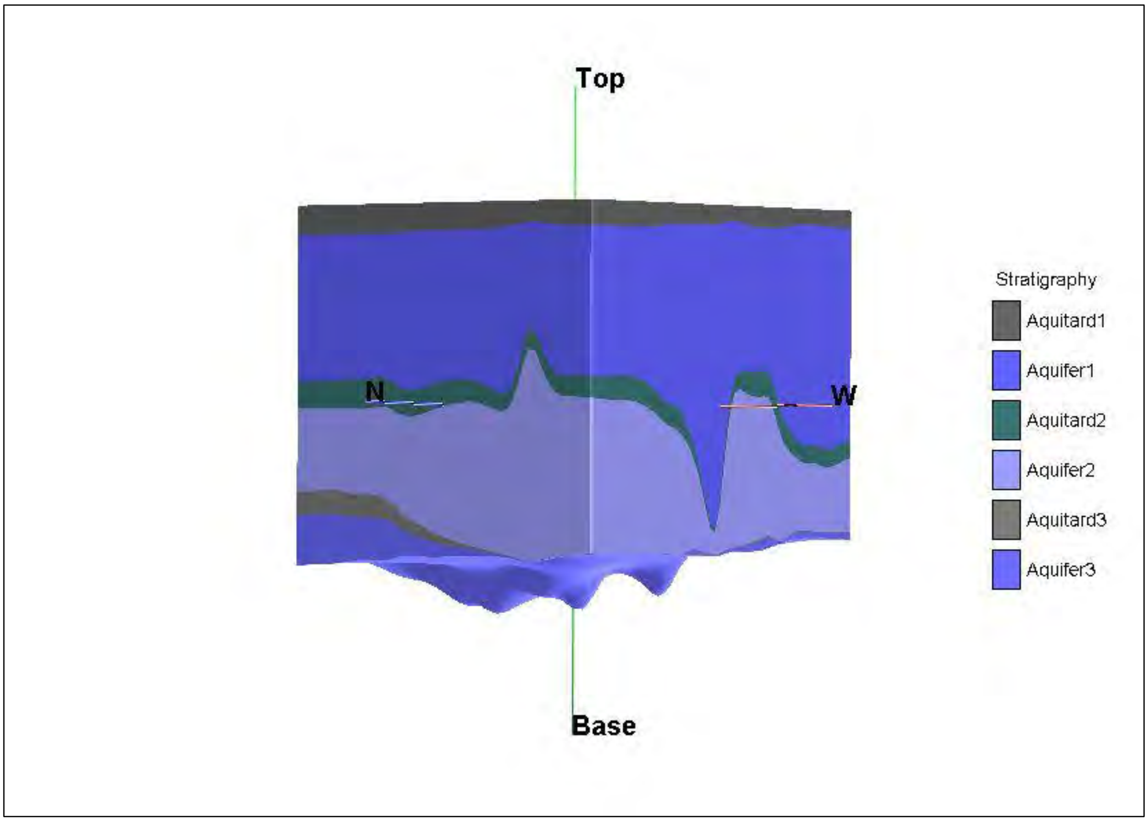


Figure 5-21: Hydrostrategraphic model for Manoharganj Upazila (SW view and NE



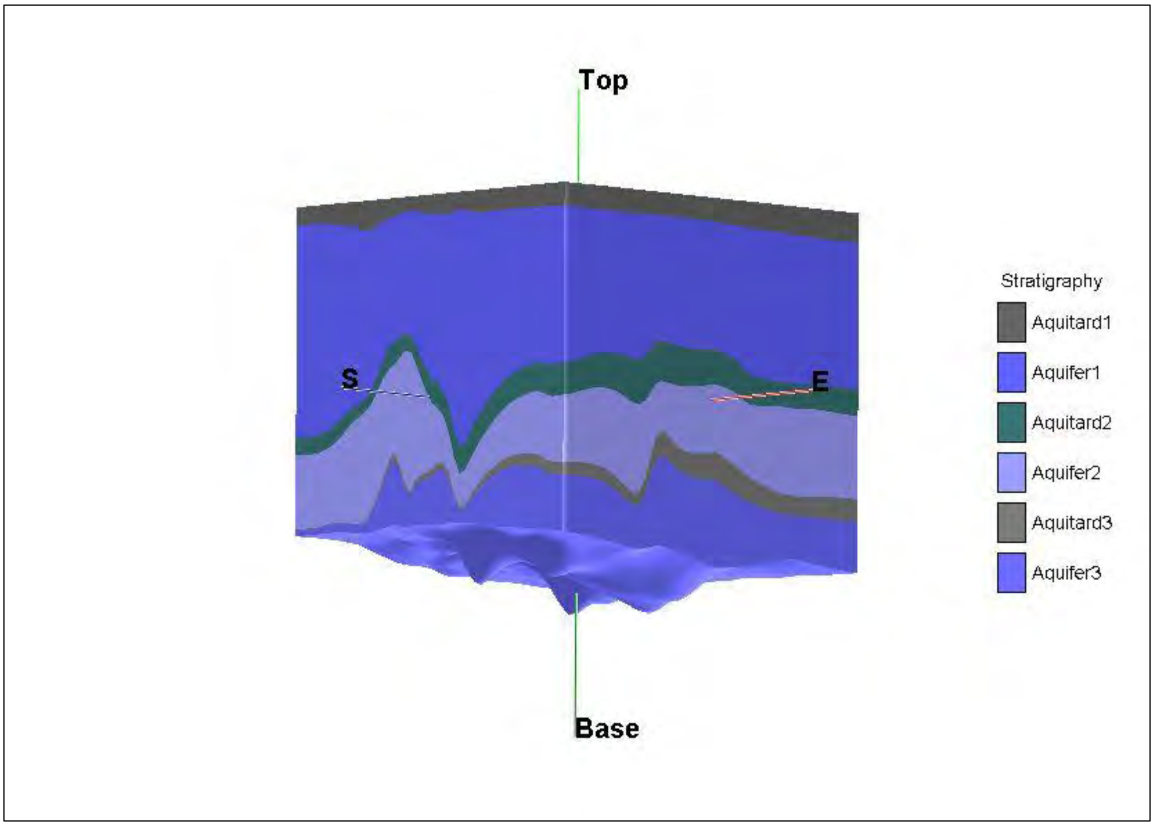


Figure 5-22: Hydrostrategraphic model for Manoharganj Upazila (NW view and SE view)

Table 5-3: Overview of the hydrostratigraphy of Manohorganj Upazila

Unit	Hydrostra tigraphy	Thickness (ft)	Comments
1	Aquitard- 1	50-80	Act as a vadose zone; composed of Clay, silty clay and silt
2	Aquifer-1	250 (avg)	Thickness increases towards western and northern direction; mainly composed of medium sands; severely arsenic contaminated
3	Aquitard- 2	30-80	Mainly composed of clay and silty clay; depth to base of the aquitard varies between 350-600ft increasing towards northern and western direction.
4	Aquifer-2	200-400	1st deep aquifer and free from As contamination; mainly composed of medium sand; become significantly thicker towards the western and northern direction.
5	Aquitard- 3	30 (avg)	composed of clay and silty clay; occur mainly in eastern and southern portion; depth to base of the aquitard varies between 500-700ft.
6	Aquifer-3	base not encountered in any of the bore holes	2nd deep aquifer and also free from As contamination; depth to the top of aquifer range between 500-700 ft and occur mainly in eastern and southern portion; composed of medium to coarse sand.

5.4.2 Borelog analysis and slurry test

Identifying fresh aquifer using slurry conductivity test

After completing the preliminary survey and water sample analyses, three deep tube wells were drilled by VERC in the eastern part of the Khila union that thought to be safe from salinity and manganese hazards. Depth of the existing neighboring deep tube wells that were producing good water quality were also considered before selecting the screened interval. But after installing these three deep tube wells in the Khila union, it was found that two of these three wells (DTW001 and DTW003) are producing water with higher salinity with EC values beyond 2000µS/cm. The detection of higher salinity in these two wells suggests that there is a strong possibility of encountering pocket saline aquifers in this Upazila that could create huge risk in future drilling of deep tube wells. Preliminary water quality survey alone is not adequate to deal with this problem.

Hence, under this study a practical tool for encountering this increased salinity problem in deep tube wells was developed. The slurry conductivity test in the field is used to identify suitable layer for drinking water that contains salts and other dissolved solids within acceptable limits for well installation.

VERC has been advised and trained to follow the guidance of Slurry test during the drilling of newly installed deep tube wells. Most of the cases sand samples were collected from the different depths/ layer of the deep aquifers and slurry EC were tested. From the measured EC values potential salinity risk were identified.

Slurry conductivity test during the drilling of deep tube wells successfully identified the fresh aquifer in every union of the studied Upazila (Fig 5-23). In this method, layers with slurry conductivity value less than 60 μS/cm mostly provided water with EC value less than 2000 μS/cm. The results of slurry conductivity tests of screened zone of the aquifer and final EC values of the water is showed in the (Table 5-4).

From the table it is clear that slurry conductivity test effectively avoided the salinity problem in the deep tube wells of the study area. Higher EC values observed in some of the wells due to higher EC values in slurry test and failure to find the layers of lower slurry EC within 800 ft depth.

Further test of Chloride in BUET lab showed that concentration of Chloride in DTWs installed by VERC not exceeded beyond Bangladesh Standards while taking the precautionary measures of slurry test during drilling.

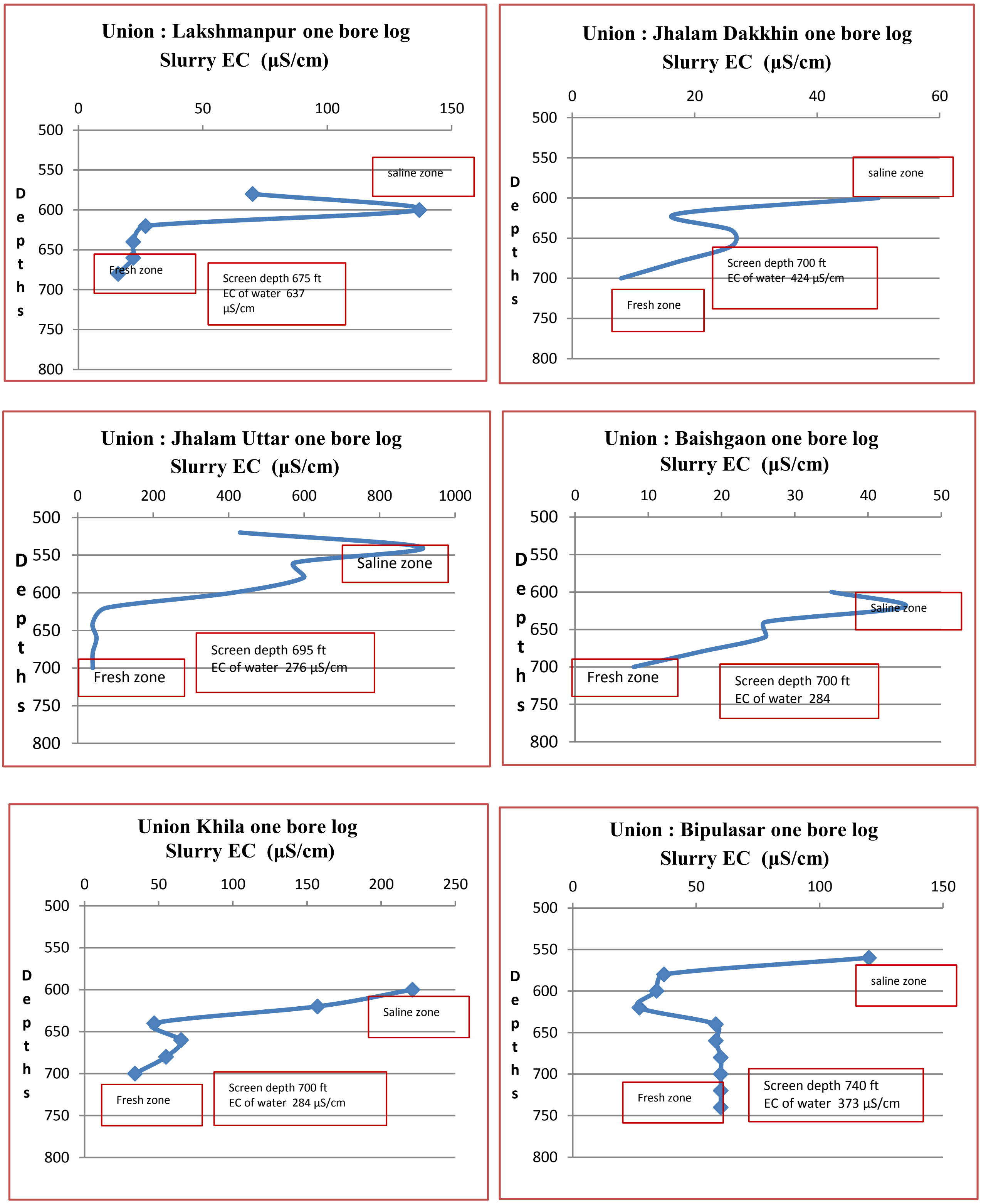


Figure 5-23: Identification of fresh aquifer using Slurry Conductivity test (sample of six unions)

Table 5-4: EC values of the sand slurries and water samples

Well ID #	Village/Community	Union	EC in slurry (uS/cm)	EC in water (uS/cm)
A1300002	Durgapur dakshin para	Baishgaon	37	996
A1300005	Udaish paschim para Baishgaon	Baishgaon	26	347
A1300006	Baishgaon pundit bari Baishgaon	Baishgaon	13	284
A3100001	Hasnabad madhya para	Hasnabad	230	1522
A3100002	Naotola paschim para Hasnabad	Hasnabad	362	3080
A3100004	Norpaia madhya para Hasnabad	Hasnabad	108	1720
A3100005	Asiadari dakshin para	Hasnabad	52	963
A3100006	Monipur paschim para	Hasnabad	237	895
A4200002	Borokestola Magistrate Bari	Jhalam Uttar	40	276
A4200006	Chonua dakshin para	Jhalam Uttar	30	291
A4200007	Chowraish purbo para	Jhalam Uttar	20	360
A4500004	pumgaon paschim para	Jhalam Dakshin	33	405
A4500005	Bochoir uttar para	Jhalam Dakshin	17	424
A4500006	Zadobpur uttar para	Jhalam Dakshin	32	613
A4500007	Mirjapur uttar para	Jhalam Dakshin	48	297
A5300002	Dishabond purbo haji bari	Khila	24	744
A5300004	Disabond dakshin para	Khila	34	284
A5900003	Moroho madhya para	Lakshmanpur	27	715
A5900004	Kharkharia paschim para	Lakshmanpur	28	853
A5900005	Moroho purbo modhya para	Lakshmanpur	16	637
A6300001	Maisatua khamar bari	Maisatua	16	474
A6300002	Taltola purbo para	Maisatua	23	325
A6300004	Batabaria uttar para	Maisatua	29	620
A6300006	Sreepur dakshin para	Maisatua	35	283
A6300007	Maisatua dakshin para	Maisatua	46	420
A8200001	Vaupur paschim para	Sarashpur	24	347
A8200003	Punchruhi purbo para	Sarashpur	19	504
A8200004	Kismotpara	Sarashpur	22	538
A9400002	Uttar hawla dakshin para	Uttar Hawla	27	547
A9400003	Dakshin Ulupara	Uttar Hawla	67	982

5.4.3 Static Water Table and aquifer response

Groundwater is not static. It is part of a dynamic flow system. It moves into and through aquifers from areas of high water level elevation to areas of low water level elevation. Groundwater level fluctuations due to aquifer storage changes involve either the addition or extraction of water to or from the aquifer, both through natural means and human involvement. Thus, understanding of the groundwater level is vital in conducting any hydrogeological investigations. In the Study area, available information on the groundwater level of deep aquifers was absent. Only the STW data has been found from DPHE for several years. Recent Water Table data has been collected in STWs and in DTWs to see the variation in aquifers. These data has been collected from 11 unions in dry season. DTWs static water levels data has been collected from VERC installed deep wells in 11 unions. On the other hand STWs static water level data has been collected from existing shallow wells that are previously installed by DPHE or individually and are mostly arsenic contaminated.

A bar Chart has been developed (Figure 5- 24) from the union wise data. It has been found that there is huge variations in static water tables in Shallow and Deep wells. In Shallow Tubewells water levels are still in suction limit, ranges from 8- 15ft from ground level (except Natherpetua). But in Deep Tubewells the water levels are mostly beyond suction limit ranges from 20 -35ft from ground level.

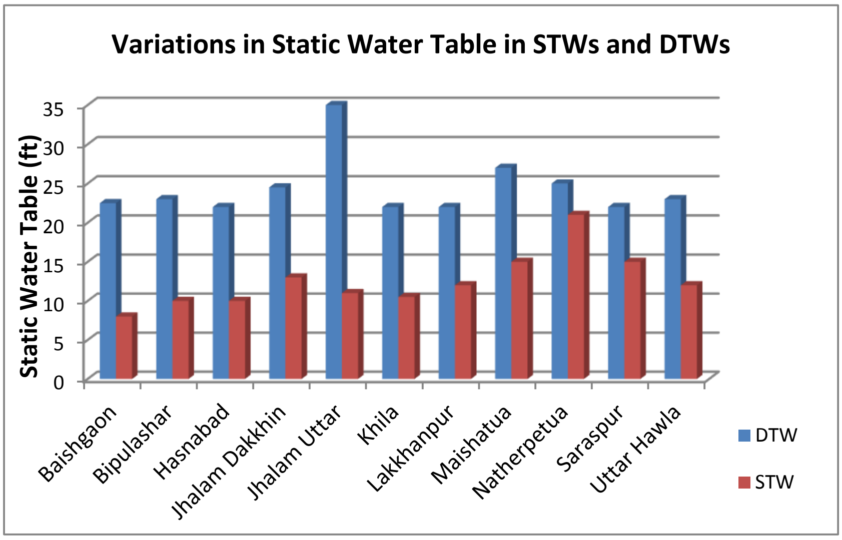


Figure 5-24: Union wise static water table variations in STWs and DTWs

A time line variation graph (Figure 5-25) has been developed from DPHE data from STWs. No DTWs data has been found from previous years in Manohorganj except 2013. Trend of lowering of Static Water Table in STWs has been found and variations is high in recent years from 2000.

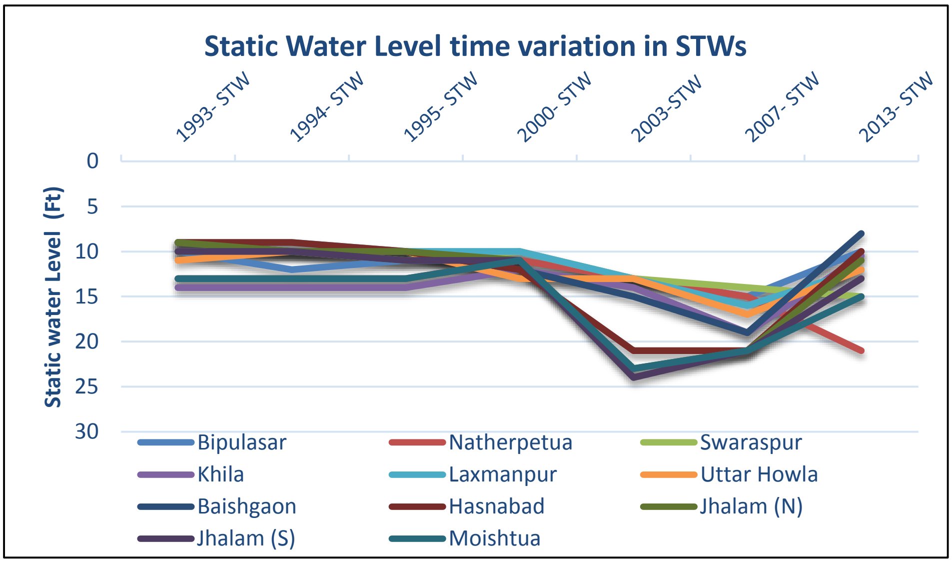


Figure 5-25: Static Water Level time variation in STWs

Shallow groundwater reservoirs in the study area recharged through infiltration of rainfall, flood water from Dakatia River; percolation from pond and low lying areas that are higher than the water table, return flow from irrigated fields and as underflow from adjacent areas of higher elevation. So, in STWs the water level is still within the suction limit. But Deep Groundwater have limited scope of recharge. Figure 5-26, shows the GIS plotting of static water table in DTWs and STWs in Study area. From this plotting it has been clear that water tables in almost all areas are within 20- 30 ft in DTWs. Whereas in STWs, water tables are within 20 ft except in very small areas of southern part.

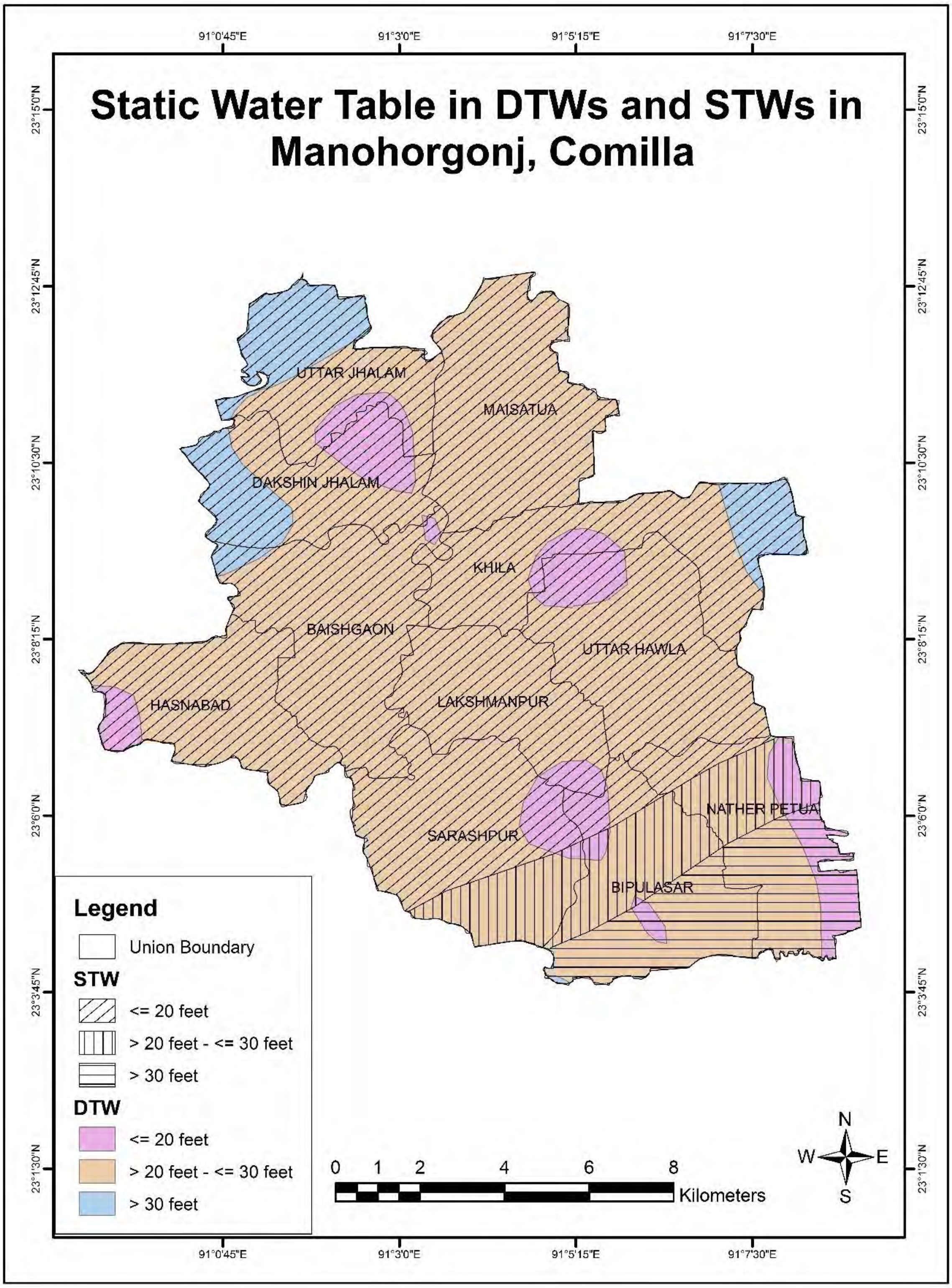


Figure 5-26: Static Water Table in Deep Tubewells and Shallow Tubewells

5.5 Safe Water Coverage and Technologies Mapping

Groundwater is the most important source of water supply in the study area like most of the rural and urban areas of Bangladesh. Other natural sources include surface water and rainwater. Surface water quality of the study area is extremely poor due to unhygienic sanitary practices and many of these water bodies are also chemically and bio-chemically contaminated due to fish culture. The availability of rainwater is limited because the rainfall intensity and distribution varies over the year and there is always a problem regarding availability of suitable catchment area. Groundwater is available at a shallow depth and in adequate quantity, but the uses of shallow groundwater for drinking purposes has become a problem due to the presence of elevated level of arsenic (average As concentration >200 μg/L). According to the DPHE/BGS (2001) report wells deeper than 150 m are mostly safe from arsenic which means most deep tube wells over the country are safe from arsenic contamination. Water samples analyses of the existing DTWs of Manohorganj also confirm this.

In Manohorganj Upazila, total 534 deep tubewells had been installed by DPHE, individually and others. Most of these wells are performing well and serving the vast population of this Upazila except 54 that became non-functional due to excessive salinity or iron or manganese. Some became nonfunctional due to poor maintenance. Out of 534 DTWs, 298 have been tested for arsenic contamination by Village Education Resource Center (VERC) in 2010 with the help of field kit and found safe from arsenic contamination.

Since June 2010, a national NGO VERC has been working with financial and monitoring support from UNICEF, to empower local governments, communities and schools ensuring sustainable interventions of arsenic-safe water, improved sanitation and hygiene behaviours in the worst-affected communities. The safe water coverage in Manohorganj has increased from 14.5% to 31.6% as a result of this project. Figure 5-27 shows, at a glance safe water coverage by technology type.

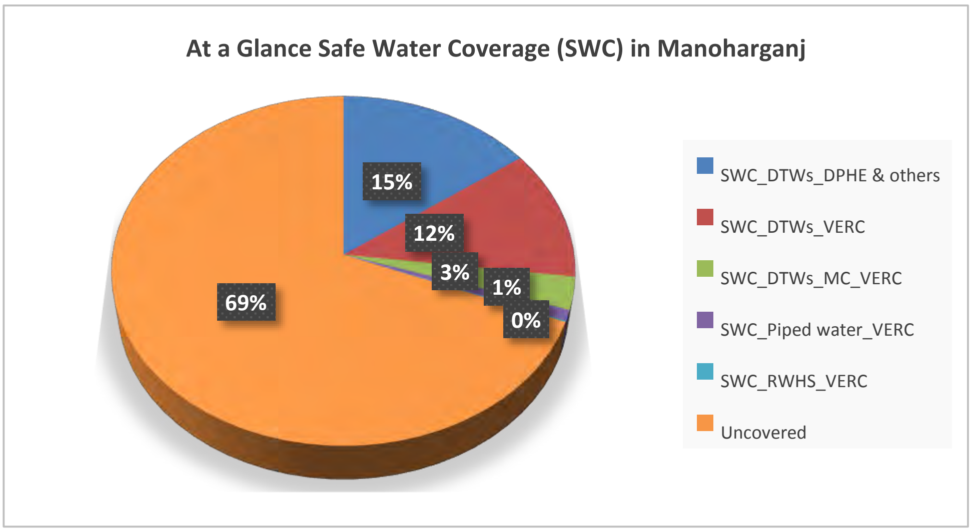


Figure 5-27: At a glance safe water coverage in Manoharganj

VERC installed 191 Deep Tubewells until 2013. Multiple connection water supplies from a single DTW also have been piloted as a source of safe and sustainable drinking water supply in Manohorganj as it reduces the cost of installation and also overexploitation of the deep aquifers. A total 63 Multiple connections provided with suction mode DTWs. However, occurrence of saline groundwater has significantly reduced development of deep aquifers and thus supply of fresh groundwater.

A total 29 Rainwater Harvesting (RWH) has been promoted to serve small and more isolated families, though it is more expensive and requires considerable maintenance.

Solar distillation panels, a major innovation for water scarce area, have been piloted at household level and at schools. This may be applicable at least for isolated pockets of exposure and perhaps more widely where both aquifers have water quality problems. As a household solution, it appears comparable in cost to rainwater harvesting.

Piped Water Supply Scheme (PWSS) had been piloted to supply around 1880 people with proper distribution network and yard connections in 2012 in Manohorganj. The management committee has been functioning well and are responsible for operation and maintenance, including caretaker selection, management and monitoring, O&M fund management, caretaker's salary, paying electricity bill, etc..

From Table 5-5, it has been found that still there is huge gap in safe water coverage. Still 68.4% population are dare need of arsenic safe water. The highest coverage union is Hasnabad (54% coverage) and the least covered union is Natherpetua (11% coverage). This variation among the unions is due to the unavailability of good quality of water in shallow and deep aquifer.

Table 5-5: Union wise safe water coverage and percent uncovered

Union	Population	# of DTWs	# of Inactive DTWs	# of MCs	# of PWSS	# of WPs safe and active	Population covered	% pop covered	% pop uncovered
Baishgaon	25,091	101	0	10	1	112	12400	49%	51%
Bipulasar	24,621	35	4	2	0	33	3600	15%	85%
Hasnabad	18,774	96	3	9	0	102	10050	54%	46%
Jhalam (Uttar)	21266	79	1	7	0	85	8250	39%	61%
Jhalam (Dakshin)	21,982	82	2	5	0	85	8450	38%	62%
Khila	22,609	44	5	3	0	42	4550	20%	80%
Lakshmanpur	17,761	73	15	9	0	67	7750	44%	56%
Maisatua	22,402	96	9	5	0	92	9850	44%	56%
Nather Petua	22,561	22	5	4	0	21	2400	11%	89%
Sarashpur	23,795	69	8	7	0	68	7250	30%	70%
Uttar Hawla	24,081	28	2	2	0	28	2900	12%	88%
Total	244,943	725	54	63	1	735	77450	31.6%	68.4%

The overall safe water coverage map (GIS Based) has been shown in Figure 5-28 to show the overall safe water coverage in whole upazila. Form this map it has been found that eastern (Khila and Uttar hawla) and south eastern part (Naterpetua and Bipulasar) of the upazilas are lack in safe water coverage. The reason behind is poor water quality in deep aquifer of eastern and south-eastern part which has already been identified in previous section 5.3. Detail union wise coverage map has been produced for all 11 unions (attached in Annex-6) with 150m service area for better identifying the unserved population at each union level. One example of Uttar Hawla union has been shown in Figure 5-29, where it has been found that 23 public DTWs and 10 private tubewells or household RWHs in this union can cover only 12% of total population of the union.

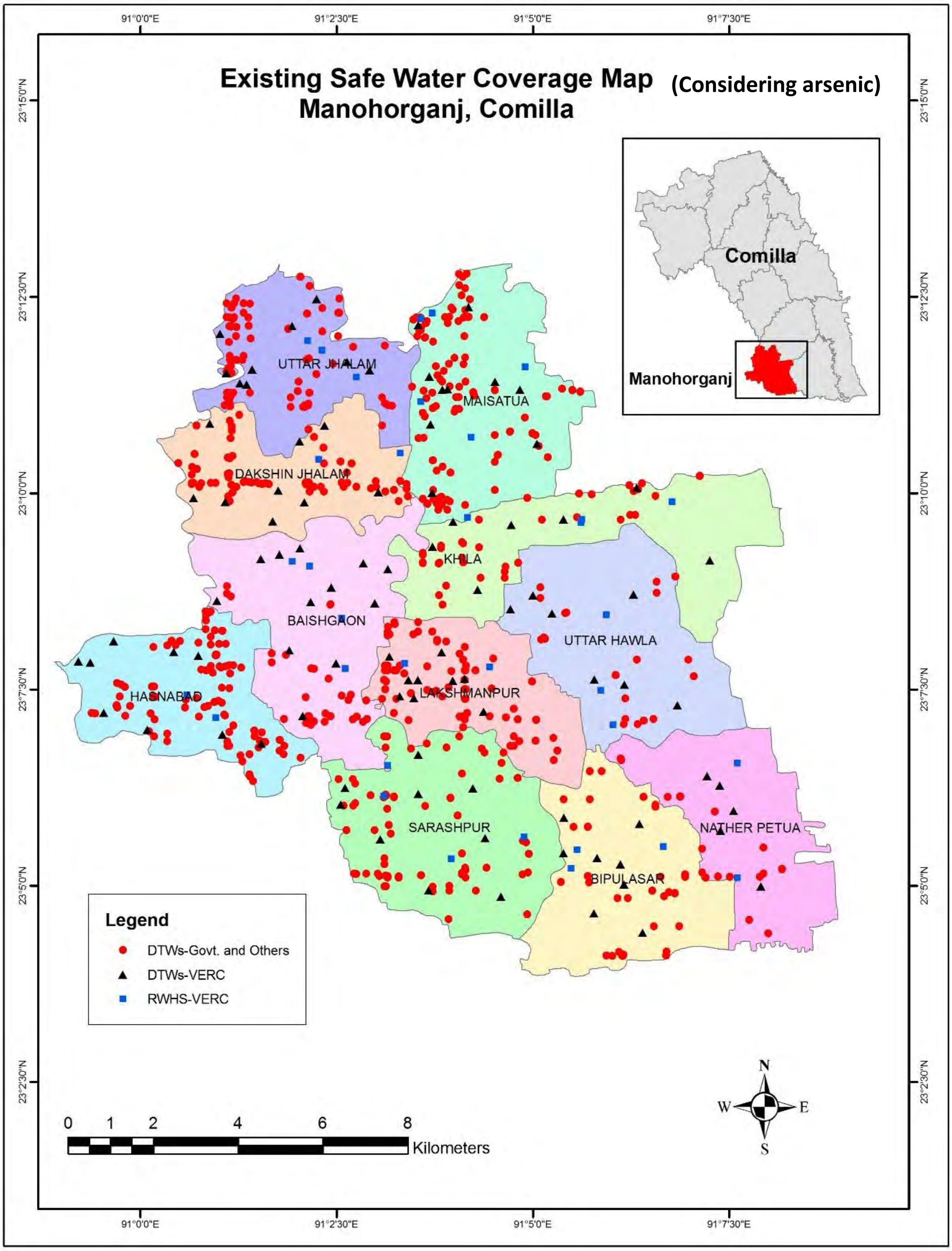


Figure 5-28: Overall Safe water coverage map of Manoharganj

Water Supply Coverage In Uttar Hawla Union

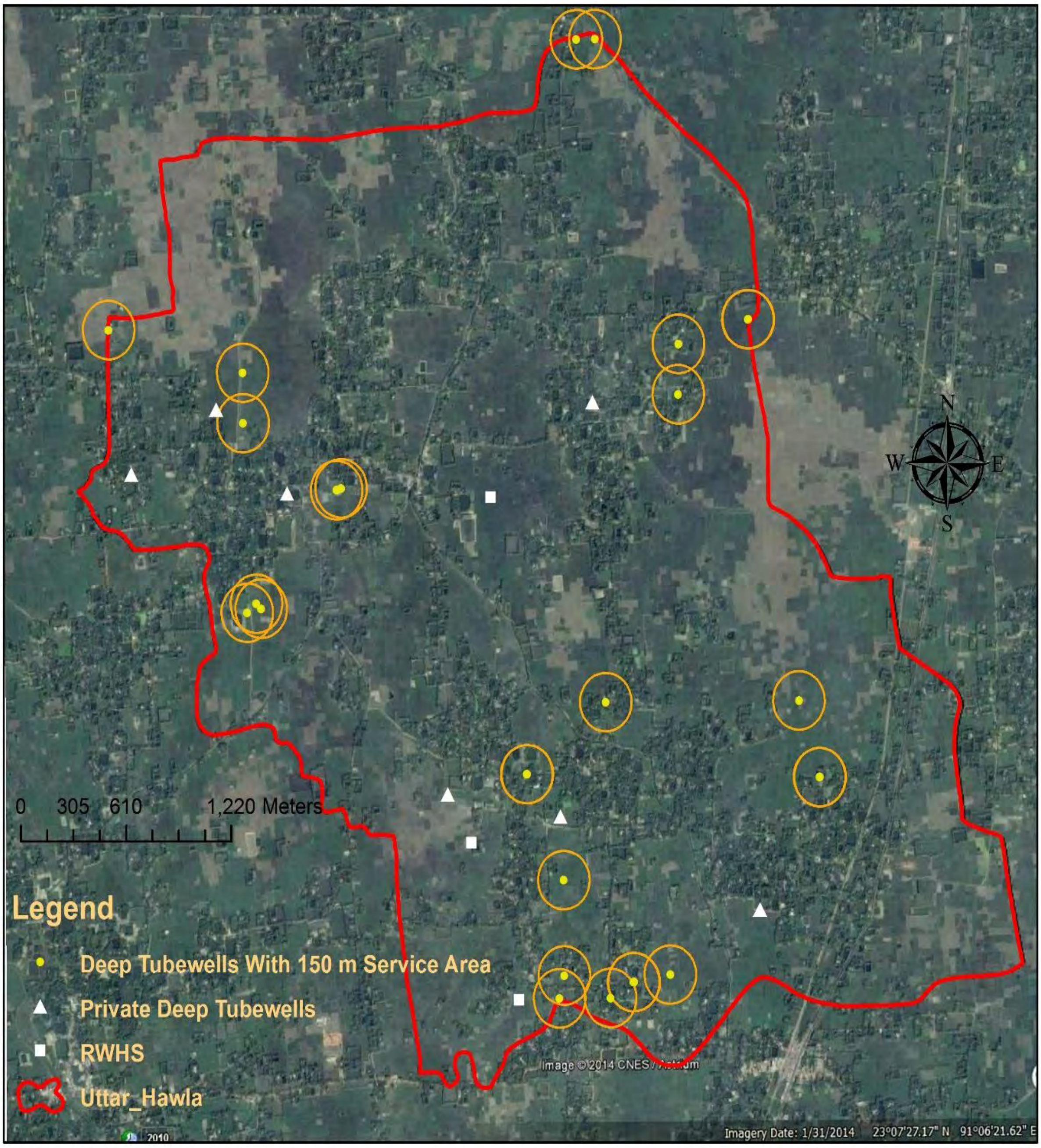


Figure 5-29: Safe water coverage with 150m service area in Uttar Hawla Union,

5.6 Performance of Arsenic Safe Water Supply Technologies

Through this study, performance and social acceptance of different arsenic safe technologies were examined. In the study area, total 227 HHs were surveyed by using structured questionnaire, where specific questions were asked to identify the user perception and experiences on user friendliness of the technologies, water quality, operation and maintenance, social acceptance, economic acceptance and level of awareness on arsenic. Answers of the each segments and questions were analyzed by using weighted values and verified by using qualitative methods. In the study area total 6 types of arsenic safe technologies are used at the households and community level. 10 Household arsenic removal units were planned to be assessed that were installed in 2009 (secondary information) but practically no arsenic removal units were found in use. Finally 227 households has been surveyed. The questionnaire survey format has been attached in Annex- 3. All questions are divided in 3 conditions; best conditions are 'good', middle conditions are 'satisfactory' and not acceptable are 'non satisfactory'. From this intensive survey, following findings have been identified in different segments.

5.6.1 Site Observation

Through site observation, over all cleanliness of the sites, platform conditions, water disposal facilities, possibilities of contamination and conditions of the technologies were Identified and analyzed. From site observation it has been found that most of the technologies are in good to satisfactory level (Figure 5-30).

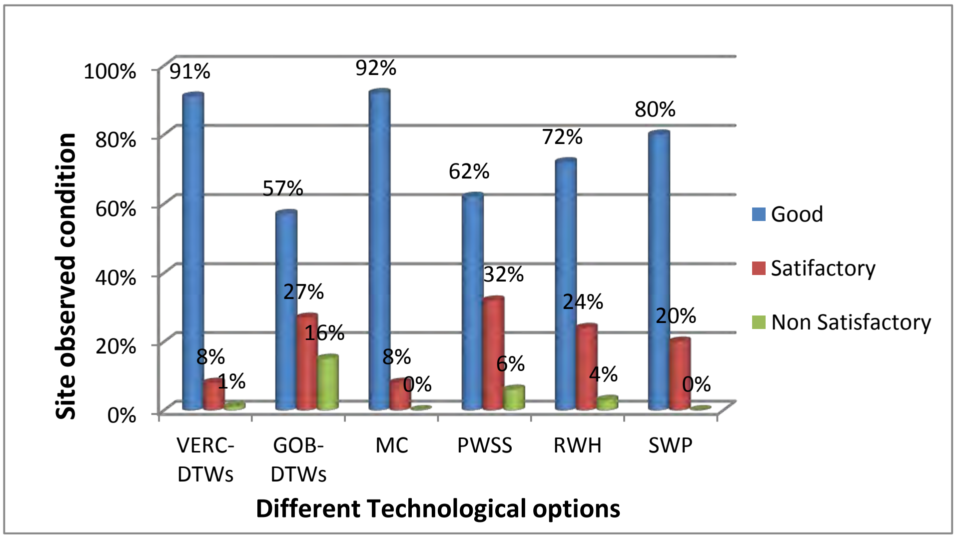


Figure 5-30: Overall satisfaction of different technologies during site observation

VERC –DTWs and Multiple Connections (MC) are achieved highest percentage. GoB – DTWs and Piped Water Supply System (PWSS) are showing comparatively lower percentage in site observation with 16% and 6% unsatisfactory status respectively. Specific question wise findings are described below:

1.1 Cleanliness and tidiness of water point or sources? From site observation it has been found that 7% of VERC –DTWs and 25% of GoB- DTWs are not clean and tidy. Other technologies found good to satisfactory level.

1.2 Condition of platform/ water collection site / rainwater storage tank? 25% platforms of GoB –DTWs found broken or damaged and have risk of microbiological contamination. 8% platforms of Piped Water Supply System are also found broken. Others found good to satisfactory condition.

1.3 Existing waste water disposal facilities (drainage facilities)? 25% of GoB- DTWs have no proper waste water drainage facilities that poses the risk of microbiological contamination. 23% of Tap Stands of PWSS also have no proper drainage facilities (Figure 5-31).

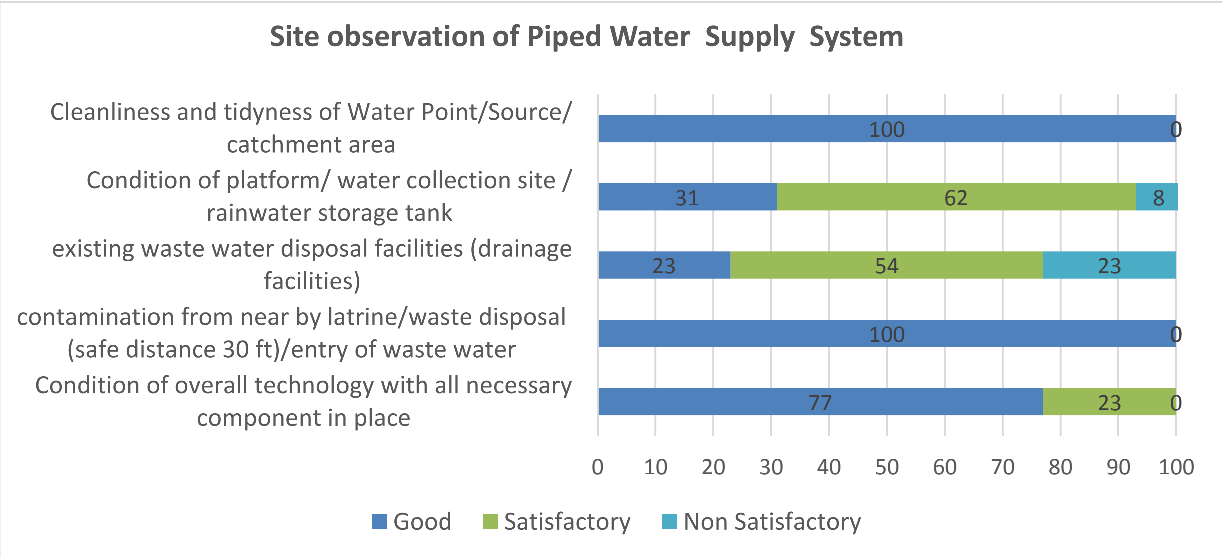


Figure 5-31: Site observation of Piped Water Supply System

1.4 Contamination from near by latrine/waste disposal (safe distance 30 ft)/entry of waste water? From site observation all the technologies found in satisfactory level.

1.5 Condition of overall technology with all necessary component in place? All the technology found in good condition accept RWHs where 13% found not satisfactory with missing/ broken parts (like tap, gutter, inflow pipe) that makes 3% overall not satisfactory situation.

It has been observed that the presence of ongoing hygiene education program continued by VERC for almost three years in this upazila created awareness among the users to keep the source clean and safe. In addition, each VERC –DTW has two trained caretakers for O&M and cleanliness of the technology. On the other hand trained caretakers are absent in GoB –DTWs that may affect the overall safety issue of water points.

In PWSS have one management committee for overall O&M of the system but 35 tap stands for cluster households are getting less attention by the management committee. 8% tap stands have broken platform and 23 % of tap stands does not have proper waste water disposal facilities (Figure 5-31). However, these tap stands are not affecting the water quality (microbiological) as like as tubewells.

5.6.2 People's perception on technologies

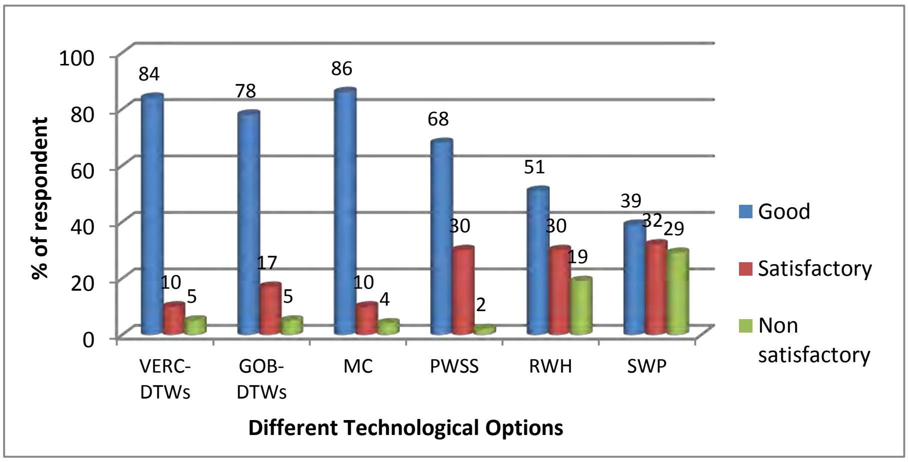


Figure 5-32: People's perception on different technologies

Under this segment peoples' perception on technologies in terms of availability and use of water in drinking and cooking purposes and longevity of technologies were collected. In general, 67% of users out 227 expressed their maximum level of satisfaction. Figure 5-32 shows that VERC –DTWs and Multiple Connections have higher level of satisfaction. On the other hand, RWH and SWP have lower level of satisfaction. Specific question wise findings are described below:

2.1 Do you drink this water? Under this Questionnaire, 100% respondents of DTWs (VERC/GoB) and MCs mentioned that they drink this water regularly. On the other hand 93% respondent of Piped Water only use this water for drinking purposes and rest of 7% prefer to drink DTW water rather than piped water. 60% respondent of Solar Water Purifier and 87% of respondent of Rainwater Harvester drink this water regularly. Rest of them use this water irregularly with other sources due to unavailability of water in SWP and RWHs.

2.2 Use this water in other purpose? 100% respondent of all technologies use this water only for drinking and cooking purposes. For washing and other purposes they use arsenic contaminated shallow wells or pond water.

2.3 Year round water availability?

Reduced level of satisfaction has been observed in PWSS, SWP and in RWHs. More than 80% respondent of DTWs (VERC/GOB/ MC) expressed their satisfaction of availability of water for whole the year round (Figure 5-33). Rest of them expressed concern about dry season problem for few months. In PWSS, due to intermittent supply of water (2 times daily) 15% of respondent said about not getting enough water all the time. In case of RWHs and SWP, respectively 93 % and 40 % respondent complained about not getting enough water year round.

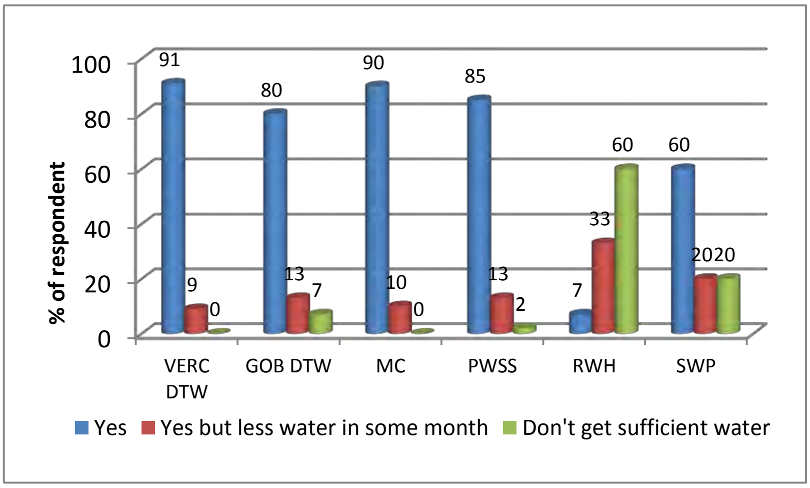


Figure 5-33: People's perception on availability of water whole the year round

2.4 Use of other sources for drinking and cooking? Overall 39% respondent mentioned that they don't use any other sources for drinking and cooking. Rest 61% respondent uses other sources only for cooking purposes but not for drinking purposes. 58% of them use pond water for cooking and 3% use nearby arsenic contaminated shallow tubewells.

2.5 Longevity of technology? More than 80% respondents of DTWs/MC/PWSS think that their technology will sustain more than 5 years. On the other hand 73% respondent of RWHs think that RWHs will sustain more than 5 years, 13% think it will sustain 3 to 5 years and rest think about less than 3 years. None of the respondent of SWP think it will sustain more than 5 years, 60% think it will sustain 3 to 5 years and 40% think less than 3 years.

A detail Chart has been provided for PWSS in Figure 5- 34. Here we found that 93% respondent drink this water. 100% of them use this water only for drinking and cooking. 85% said water is available whole the year round. Among them 91% use pond water for cooking.

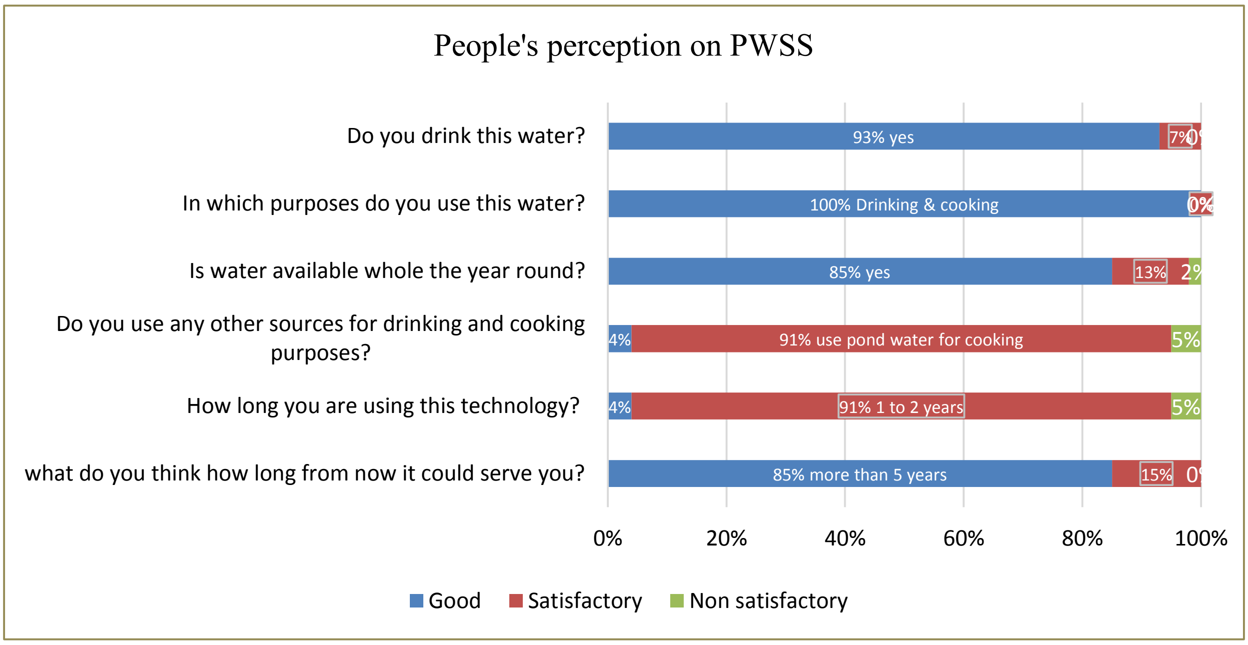


Figure 5-34: People's perception on Piped Water Supply System

5.6.3 People's Perception about the water Quality

In this segment of household survey, people's perception about water quality were assessed by considering taste, smell, iron/ manganese, arsenic contamination and salinity. In general 80% users out of 227 are satisfied at the maximum level and not complained regarding the taste and smell or quality. People's perception on water quality for VERC –DTWs and multiple connections are highest (Figure 5-35) which is around 86% and 84%. 23% respondent of PWSS complain little on taste, smell and iron problem but in satisfactory level. 21% respondent of RWHs and 26% of SWP complained about taste or don't know whether it is arsenic safe or not.

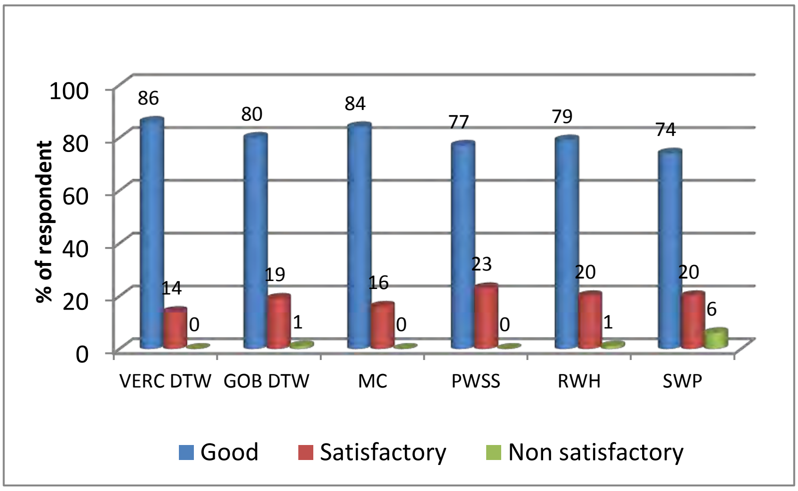


Figure 5-35: People's perception on Water Quality for different technological options

Specific question wise findings are described here:

3.1/ 3.2 How is taste and smell? Respondent of VERC DTWs and MCs have almost no complain about taste and smell. Respondent of Piped Water Supply System (PWSS) have little complain about taste and smell which is in acceptable limit though there is no physical evidence found of bad taste and smell. Respondent of Rainwater Harvesting System (RWHs) complain about taste (27%) but that is in acceptable limit.

3.2 Is there iron / manganese problem? 73% respondent of VERC-DTW and 100% of MCs respondent said about the presence of iron that is within their acceptable limit. The same findings have been found in GOB DTWs too. 80% of respondent said about the presence of iron but within acceptable limit. 58% respondent of PWSS also said about presence iron problem which in their acceptable limit. Most of the cases they could not recognize manganese.

3.3 Is water Salty? No one complain or said about salty water accept PWSS, where 4% respondent said little bit of salt in water but okay to drink.

3.4 Has the water been tested for Arsenic? Overall 7% respondent have no information regarding arsenic testing and 10% don't know when tested.

3.5 Is there arsenic in water? 20% respondent of GoB- DTWs, 47% respondent of RWHs and 100% respondent of Solar water purifier don't know whether this technology is arsenic safe or not.

A detail Chart has been provided for PWSS on water quality aspects in Figure 5-36.

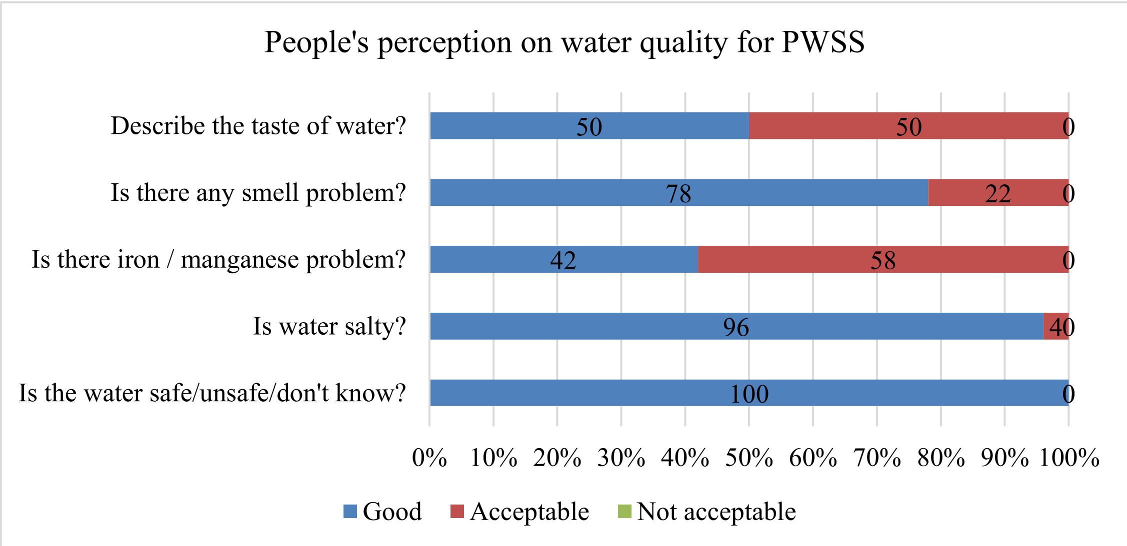


Figure 5-36: People's perception on water quality for PWSS

5.6.4 Social Acceptance of different technologies

Through this segment of survey, social acceptance of different technologies were assessed. Water collection time, distance, social conflict during water collection were considered as the major determinants of this segment. Respondent of VERC- DTW and Multiple Connections expressed their highest level of satisfaction (Figure 5-37) which is around 92% and 88%. Next higher level satisfaction found in PWSS which around 81%.

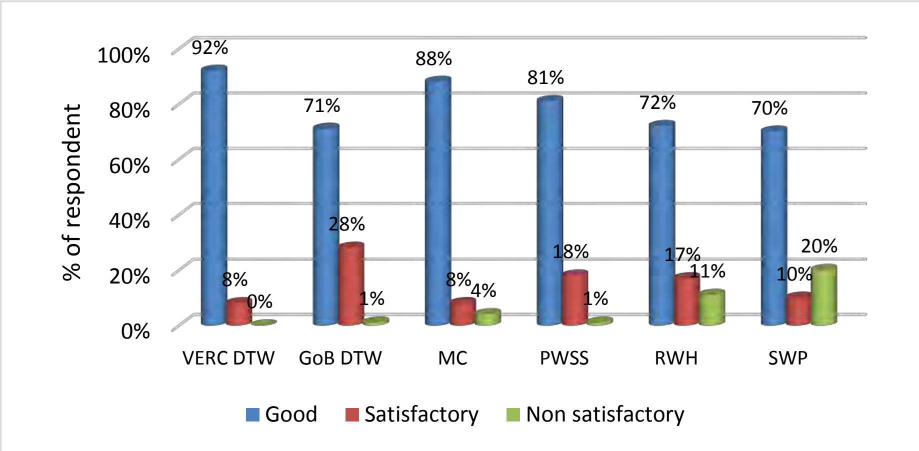


Figure 5-37: Social acceptance of different technologies

Specific question wise findings are described below:

4.1 Is the water facility easy to operate? 100% respondents said it is easy to operate.

4.2 Is the water collection time reduced compared to previous when they have to collect safe water from distance? 100% respondents said that water collection time reduced compared to previous.

4.3 Do you face any problem/ conflict/ uncomfortable when collecting water? Overall 7% respondent said they face social conflict sometimes when collecting water.

4.4 In case of non-availability of arsenic safe water how far are you willing to travel for arsenic safe water? 31% respondent are not agreed to go far to collect arsenic safe water in case of non-availability of arsenic safe water. On the other hand 69% are willing to go as far as they need to collect arsenic safe water.

5.6.5 People's perception on O&M of different technologies

From the household survey, it has been found that operation and maintenance is one of the major challenges for each of the arsenic safe technology. Overall level of satisfaction is 70% good and 17% satisfactory level (Figure 5-38). The common concern is defined person for O&M and unavailability of spare parts at the local market. Specific question wise findings are described below:

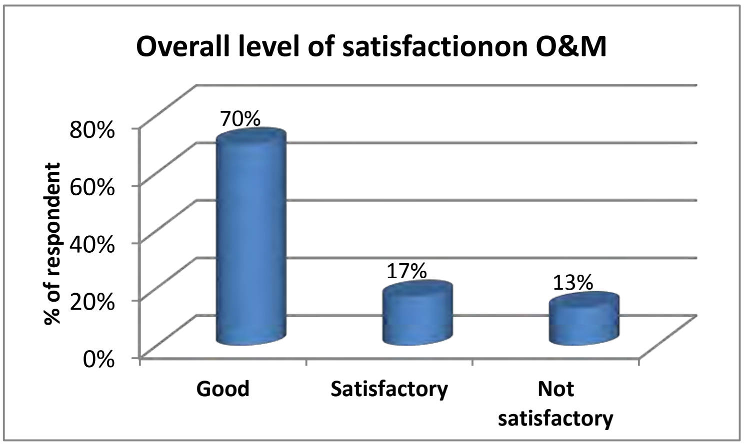


Figure 5-38: Overall level of satisfaction on O&M

5.1 Who does the maintenance? 51% respondent of VERC DTW said about defined caretaker who does the maintenance, 22% said it is done by owner of the land and 26% said they don't know. In GoB DTW, only 27% can say about caretaker, 40% said it is done by land owner and 33% don't know who does the maintenance. The respondent of Multiple Connections also replied the same. Only the 100% respondent of PWSS said about defined caretaker for the system. RWS and SWP are mostly household based and maintenance done by the household.

5.2 Is maintenance of the water facility easy? High level of satisfaction found in VERC DTW (73%), Multiple Connection users (80%) and GoB DTW (67%). Most of the PWSS users (63%) expressed medium level of satisfaction. 13% users of RWHs and 40% users of SWP expressed that maintenance is not easy.

5.3 How many times it breakdown in last one year? 40% respondent of GoB DTW and 11% of VERC DTW expressed that this technology need repair more than 3 times. 28% Respondent of PWSS said that it has been breakdown 2-3 times in last one year, which was due to electricity problem of that area.

5.4 How many days it takes to repair it? 33% respondent of GoB DTW and 40% respondent of PWSS and 20% respondent of RWHs said that it took more than 5 days to repair

5.5 Is spare parts/media of the facility available? 28% respondent of VERC DTW and 13% of GoB DTW and 40% of RWHs expressed concern that they had to collect spare parts from far distance. Overall 3% said spare parts are not available in local market. 100% respondent of SWP expressed their concern that the spare parts for this technology are not available in local market.

Technology wise level of satisfaction on O&M has been shown in Figure 5.39 where we have found that 66% respondent of VERC –DTWs and 85% respondent of MCs said ‘Good’ for overall O&M as there is defined caretaker and available services. On the other hand GoB- DTWs are low in perception which is 50%.

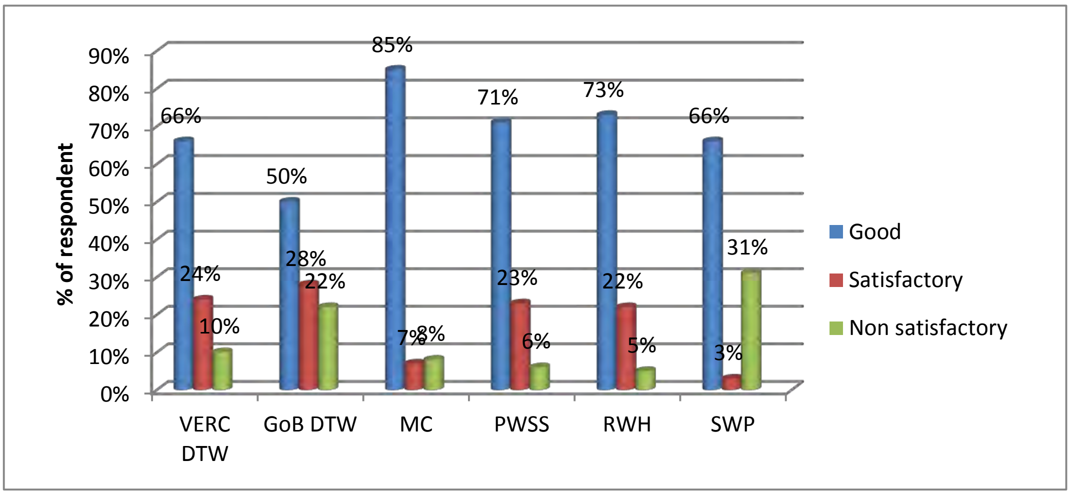


Figure 5-39: People's Perception on O&M for different technologies

5.6.6 People’s perception on Economic Benefits:

In this segment of survey, cost of installation, affordability of contribution money, sharing the cost of operation and maintenance has been considered. Higher percentage of maximum level of satisfaction found (Figure 5-40) among the users of MC (94%), PWSS (87%) and VERC DTW (86%). Lower percentage of maximum level of satisfaction found among the users of RWH (76%), GoB DTW(74%) and SWP (0%).

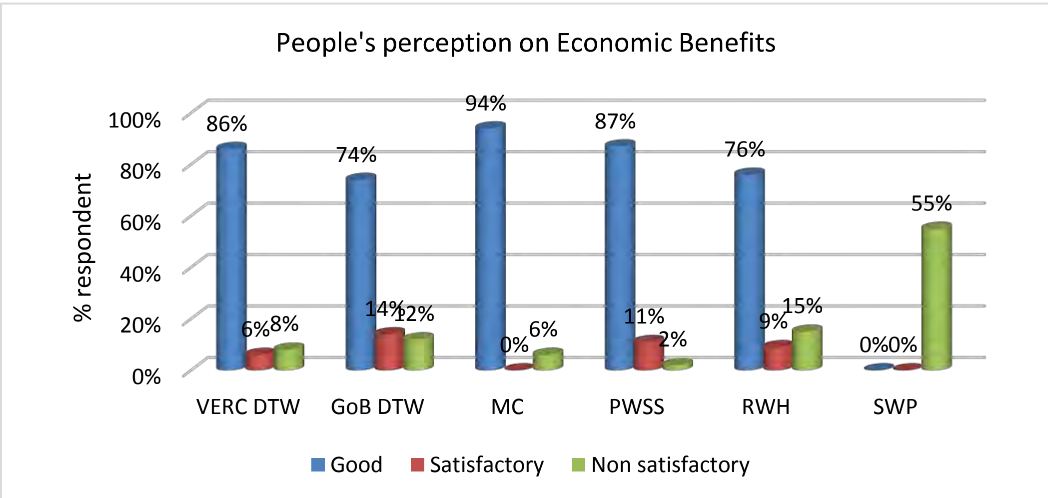


Figure 5-40: People's perception on economic benefits for different technologies

Specific question wise findings are described below:

6.1 Is the cost of the water facility is reasonable? 60% respondent of GoB DTW, 30% of VERC DTW and 20% respondent of MC expressed that technology is very costly. 53% respondent of RWHs and 100% respondent of SWP also expressed that these technology is very costly. On the other hand only 9% respondent of PWSS think this is very costly. Overall 40% respondent think that these technologies are costly to very costly and rest 60% think these are reasonable.

6.2 Is the contribution money of the water facility reasonable for you? Most of the respondent of the different technologies expressed that the contribution money (capital cost sharing) taken by GoB and NGOs are reasonable. Only 26% respondent of RWH, 21% respondent of DTWs and 13% of PWSS expressed that the contribution money is very high to high for them. Users of SWP did not contributed any capital cost.

6.3 Is the O&M cost of the facility reasonable? Most of the respondent of the different technologies expressed that the O&M cost of the facility is reasonable. Only 14% respondent of GoB DTW and 7% respondent of PWSS expressed that the contribution money is high for them. Also, 100% respondent of SWP think that O&M cost would be very high as spare parts of this technology are not available in local market.

6.4 Are you paying the contribution money willingly? Overall findings is that 87% of respondent paying the contribution money willingly. 10% of respondent expressed that they are not willing to pay but due to social pressure and 3% are paying by force. 97% respondent of VERC- DTWs said that they pay willingly (Figure 5-41).

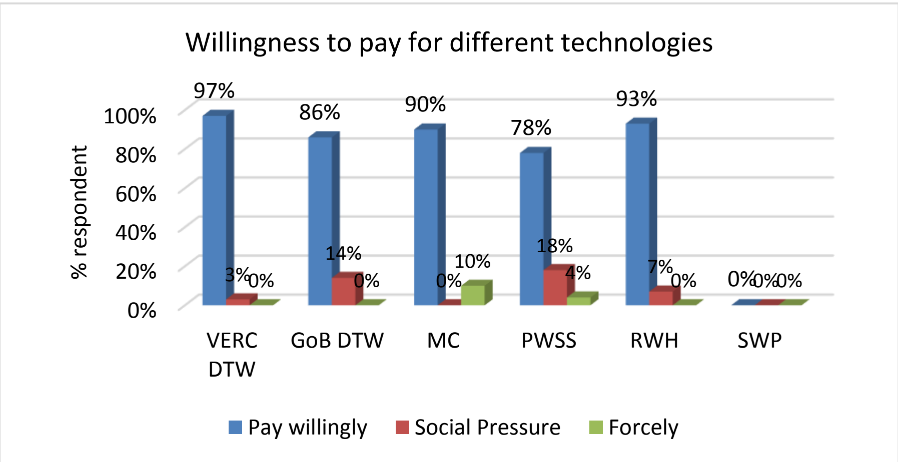


Figure 5-41: Willingness to pay for different technologies

6.5 How much are you willing to pay? (if 6.4 answer is 'NO') out of 227 respondent 5 said they don't want to share any cost, 18 said 25% cost of present contribution money is fine for them and 4 said 50% of present contribution money is fine for them.

5.6.7 Level of awareness among the users

It has been found that (Figure 5-42) nearly 91% of respondent out of 227 have the knowledge that arsenic contaminated water is not safe to drink. 28% knows arsenicosis patients and can tell the name who live in their village or in neighboring family. 50% knows where to go when arsenicosis symptoms observed. 85% said that medicine for arsenicosis patient are not available in local dispensary. 71% knows medicine could be found in Upazila Health Complex and rest don't know where it could be found.

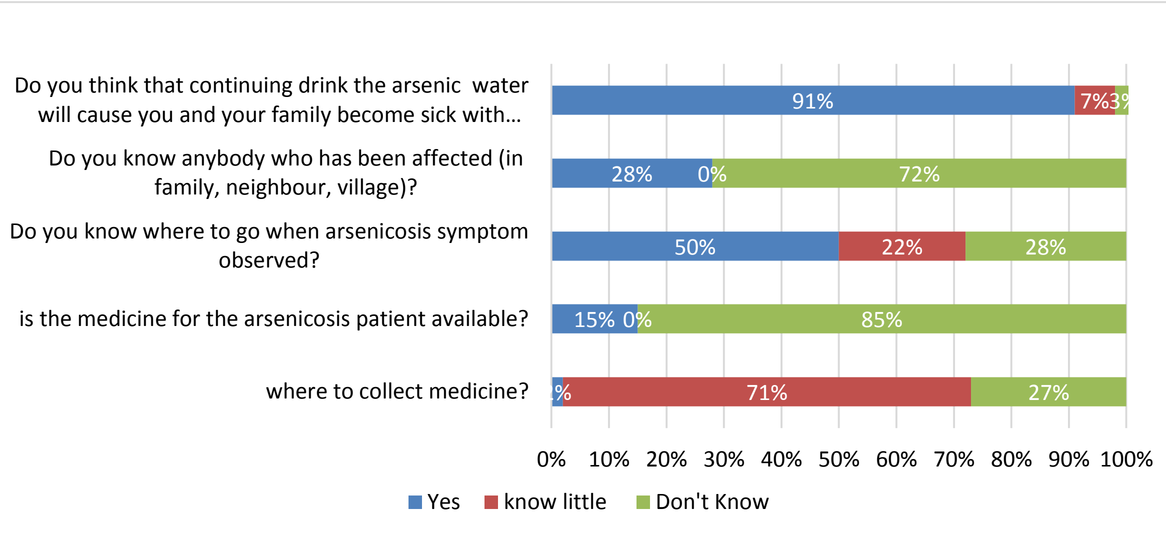


Figure 5-42: Overall level of awareness on arsenic issues among users

According to questionnaire survey, they can also identified some of the social benefits of having arsenic safe water for drinking and cooking. From Figure 5-43, 94% can state at least one health benefit such as; a. improvement of Arsenicosis patient, b. reduce risk of having arsenicosis, c. overall health improvement. 87% can state at least one economic benefit such as; reduced a. medicine cost, b. cost of working day loss, c. cost of lives, d. cost of family time loss. 86% can state at least one social benefit such as; a. children attending school, b. marriage in time, c. cost of lives, d. cost of family time loss.

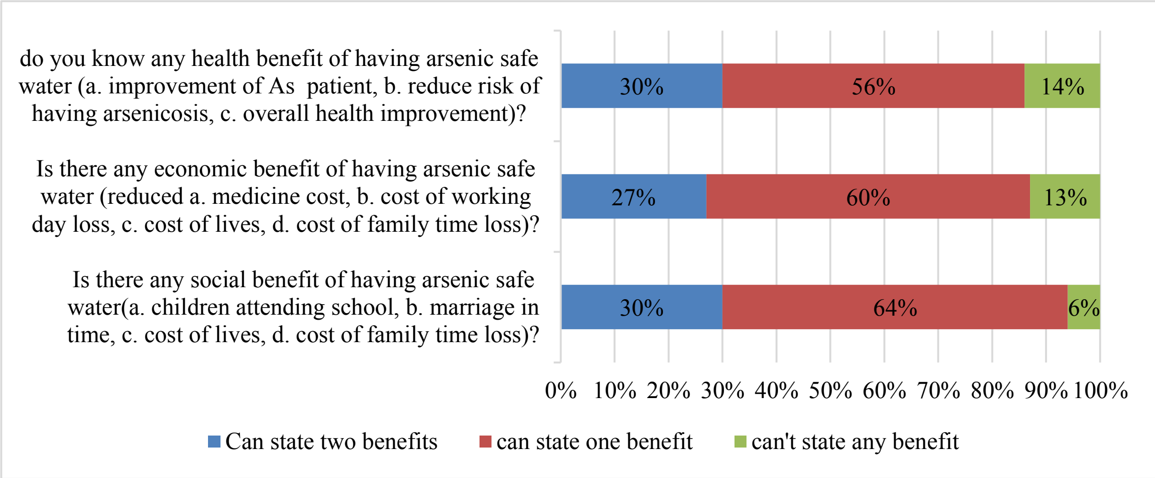


Figure 5-43: Understanding of benefits having arsenic safe water

The overall level of awareness are 71% (Table 5-7) at satisfactory level that can be said as medium to high. Also the benefits of arsenic safe water known to 78.5% (Table 5-7) people. This is may be the effect of awareness program continued by VERC for last three years.

5.7 Water Quality Test Results of Technologies Surveyed

A total 48 samples were collected and tested in BUET lab. Samples were collected from different unions for different technologies based on the Households surveyed. Four parameters has been tested for each samples that includes arsenic, iron, manganese and chloride. According to the test results none of them exceeds Bangladesh standards for arsenic and chloride. On the other hand most of the DTWs exceeds Bangladesh standards for iron and few exceed for manganese but not exceed WHO guideline for manganese. The Water Quality test results from BUET laboratory has been attached in Annex-5. Faecal coliform test has been done with Pota Test- field test kits for all technologies assessed including RWHS. A summary of water quality tests results has been shown in Table 5-6.

From Table 5-6, it has been found that 100% sample exceeds Bangladesh standards for iron and 17.5% samples exceeds for manganese. According to WHO guideline for drinking water, iron is not a health issue rather an aesthetic issue. So I have considered iron upto 5mg/L which is acceptable in rural context of Bangladesh. Also considered WHO guideline for manganese which is 0.4mg/L.

Table 5-6: Water Quality Assessment for technology assessment

Technology tested	No. of technologies tested	Percentage within Bangladesh standards (BUET Laboratory testing)				Faecal Coliform testing (Pota Test- field test kit)	Remarks
		Arsenic	Manganese	Chloride	Iron		
DTWs- VERC	28	100%	79%	100%	0%	86%	
DTW-GoB/ private	6	100%	83%	100%	0%	67%	
MC attached with DTWs	5	100%	100%	100%	0%	80%	
PWSS	1	100%	100%	100%	0%	84%	13 Tap points tested
RWHS	15	-	-	-	-	60%	Only FC tested
SWP	5	100%	100%	100%	100%	100%	

These test results were used to produce technology performance assessment matrix in Table 5-7.

5.8 Existing Technologies Performance Matrix

In this performance matrix (Table 5-7), existing water supply technologies were ranked considering water quality, water availability, sustainability, cost effectiveness, people's perception and social acceptance. Proffered water supply technologies were ranked as

1. Multiple connections attached with DTWs,
2. Deep Tubewells,
3. Piped Water Supply System,
4. Rainwater Harvesting system
5. Solar Water Purifier

Table 5-7: Existing Technologies Performance Matrix

				Water quality						Availability		Sustainability			sustainable, safe, year round drinkable water (X)	cost effectiveness				people's perception			Social acceptance (considering 'Good')	People's perception and social acceptance (Y)				Awareness at satisfactory level	Benefits of arsenic safe water known
Existing Water Supply Systems	No. of technology surveyed	No. of household surveyed	drinking water regularly (%)	As < 50 ppb (%)	Mn< 0.4ppm (%)	Cl< 600 ppm (%)	Fe< 1.0 ppm (%)	Fe< 5.0 ppm (%)	Ecoli< 10 /100 ml (%)	satisfactory Yield (%)	seasonal availability (%)	safe at source (site observation-'Good')	O&M system in place (consider 'Good')	Spare parts are redily available		persons served per technology	Nominal cost/technology	cost / person	willingness to pay/ contribution per person	people's perception on Technology is 'Good'	people's perception on WQ is "Good"	people's perception on Cost 'Resonable'			(X+Y)/2	Ranking of Water Supply Systems	Preferred Water Supply Technologies		
										%	%	%	%	%	%	nos	Taka	Taka/p	Taka/p	%	%	%	%	%				%	%
DTW -VERC (suction mode)	28	135	100	100	100	100	0	87	85.71	100	91	91	66	69	89.97	209	65,000	311	19	84	86	60	80	77.5	83.737	2	1. MC attached with DTWs 2. Deep Tubewells 3. Piped Water Supply System 4. RainWater Harvesting Systems 5. Solar Water Purifier/Arsenic Removal Technologies	65	85
DTW -GoB/private (suction mode)	6	16	100	100	100	100	0	83	66.67	100	80	57	50	86	83.88	138	65,000	473	29	80	80	33	70	65.75	74.8144	4		67	79
MC attached with DTW	5	10	100	100	100	100	0	87	80.00	100	90	92	85	100	94.00	75	25,000	334	27	86	84	80	88	84.5	89.25	1		71	95
Piped Water Supply System	1	46	93	100	100	100	0	0	84.62	100	85	62	71	93	80.78	1880	2,000,000	1064	106	68	77	82	81	77	78.8916	3		99	86
RWHS	15	15	87	100	100	100	100	0	60.00	53	7	80	73	60	74.55	6	18,000	3000	300	51	79	27	82	59.75	67.1477	5		72	66
SWP	5	5	60	100	100	100	100	0	100.00	0	60	72	66	0	68.91	6	30,000	5000	n/a	39	74	0	68	45.25	57.0795	6		53	60
																												71.1667	78.5

5.9 Final assessment and recommended technology matrix

Manohorganj is highly affected by arsenic contamination. In addition, the presence of salt, manganese and iron problems in deep groundwater affects the use of Deep Tubewells. Combining survey data has resulted in significantly improved targeting of well installation. Slurry tests conducted during drilling permits the layer with fresh water to be targeted for well installation, avoiding costly mistakes that a deep well is installed to brackish groundwater. Multiple connection attached with Deep Tubewells have also been promoted to serve more people with arsenic safe water in a cost effective way. But recent findings of lowering of water table are becoming a concern for promoting multiple connections and suction mode DTWs.

Piped Water Supply Scheme (PWSS) had been piloted to supply around 1880 people with proper distribution network and yard connections in 2012 in Manohorganj. The management committee has been functioning well and are responsible for operation and maintenance, including caretaker selection, management and monitoring, O&M fund management, caretaker's salary, paying electricity bill, etc. But yet to see whether community is continuing O&M without having any follow-up support from NGO.

Rainwater Harvesting (RWH) has been promoted to serve small and more isolated families, where both aquifers have water quality problems. It is expensive, concern as year round solution and requires considerable maintenance.

Solar Water Purifier or Solar Distillation Panels, a major innovation for water scarce area, have been piloted at household level and at schools. This has been provided in isolated pockets where both aquifers have water quality problems. This is also expensive, low water production and requires considerable maintenance.

Based on the results and findings of the current study, final assessment for future water supply technologies choice were done considering the technological aspects, social aspects and economic aspects.

5.9.1 Technological Aspects

It is evident that there are no simple and inexpensive technologies available to mitigate the arsenic and other water quality problems in Manohorganj upazila. This is also true for all over the country in Bangladesh. Many alternative technologies avoiding arsenic and treatment technologies of arsenic contaminated water at the household and community levels have been developed and installed in different parts of Bangladesh. Some have shown good but limited potential for use in arsenic-safe water supply in affected areas, while others have serious drawbacks. The situation further get complicated when other water quality problems such as; iron, manganese and chloride also present in deep groundwater. Following technologies have been proposed for severely arsenic contaminated Manohorganj upazila that are also contaminated with other chemical parameters and lowering water tables. People's preference has also been considered.

1. Force Mode Deep Tubewells TaraII / Tara Dev could be the first choice for the unions where lowering water table and arsenic in shallow aquifer is the major problems. Lowering of static water tables is a big concern for providing suction mode Deep Tubewells. Previous data showed the static water tables in Shallow Tubewells is not alarming and no data were available for Deep Tubewells. Existing suction mode DTWs (# 6) have high level of people's preference and also the multiple connections attached to it. But the static water table measured in Deep Tubewells through this study are found alarming. Almost all unions water tables are in marginal level of suction limits (around 23 ft) and some are already beyond suction limit and getting hard to pump during dry season. In this situation, suction mode DTWs will not be feasible anymore for this 11 unions of Manohorganj upazila. In addition, multiple connections will not be feasible as it is not possible with force mode DTWs.

   In other areas, this technology could be thought very carefully. Slurry Electrical Conductivity test might help to avoid brackish groundwater of deep aquifer. In addition, skilled mechanics need to be engaged to carefully select the sand layer for strainer avoiding iron and manganese as much as possible.

2. From hydro stratigraphic analysis it has been found that eastern and southern part have 3 aquifers within 700ft. Most of the tubewells of this part installed in this 3rd aquifer. On the other hand the western and northern part 3rd aquifer is missing within 700ft and all drilling done in 2nd aquifer which is producing good quality water comparing 3rd

aquifer in east and south. Suggesting to explore the intermediate aquifer (350ft- 500ft) for drilling in eastern and southern part of this upazila to observe the water quality. Exploring intermediate depth in unions (Bipulasar, Khila, Laxmanpur, Uttar Hawla) will be an opportunity to find a good quality of water.

3. Piped Water Supply System (PWSS) could be the major choice for most of the unions as long term safe and sustainable solution. This system will be fitted with simple iron removal plant or treatment plant depending on the water quality problem of that area.

   Iron is the common water quality problem of all the 11 unions of Manohorganj. 9 out of 11 unions have iron more than 5mg/L whereas '*Bangladesh Drinking Water Standards'* for iron is 1mg/L. However, there is no health based guideline value for iron in *'WHO Guideline for Drinking Water'*. Department of Public Health and Engineering (DPHE) follow 5mg/L iron for the point source of rural water supply system considering the people's acceptance upto that level. For PWSS, iron removal plant should be considered when it is more than 1.0 mg/L.

   Manganese is another growing concern for all over Bangladesh. Though it was not recommended as health hazard chemical in 4th edition of *'WHO Guideline for Drinking Water*' but set a guideline value (0.4mg/L) considering aesthetic point of consumers. We followed WHO guideline value here. We found manganese is higher where iron and chloride is also higher. In this situation, proper treatment or removal plant is necessary to provide safe and sustainable water supply technologies.

4. Managed Aquifer Recharge (MAR) could be next choice for the areas of high iron, manganese and chloride. This innovative technology has been promoted in saline prone coastal areas of Bangladesh after a successful research.

   The application of the MAR concept in Bangladesh is simple: water is collected from ponds and roofs (after passing through a sand filter), and then injected into the shallow saline aquifer through a ring of infiltration wells, creating a lens of fresh water. After the turbidity of the water has improved to an acceptable level, water can be abstracted using a standard handpump yielding water of generally improved quality (reduced levels of turbidity, coliforms, iron and arsenic), which is available throughout the year. Each scheme can serve several hundred people and importantly, can be easily maintained by community groups.

5. Rain Water Harvesting (RWH) system should be promoted as usual. To use water effectively without wastage and maintaining the high level of safety during collection and preservation are the major concern for this technology. The user household should be oriented on the proper use and maintenance of the system. In addition to orientation, household based strong awareness programme will be necessary to make this technology popular and sustainable. This technology have huge opportunities in severely water quality problem areas like Manohorganj.

6. Solar Water Purifier or Arsenic Removal Technologies could be the last options in areas of high iron, manganese and chloride. We found three households out of 10 to 12 households who were using Sono Filter provided by DART/BEST Project of UNICEF/DPHE/ICDDR'B five years before. These three households stopped using the technology 3 to 4 years back after it got clogged. There is no trace of filter at this moment. This technology needs further attention to make it sustainable. Creating supply chain for spare parts and media and orientation to users on the proper O&M are major areas to work. Moreover strong awareness programme is recommended so that people understand the importance of arsenic safe water and dedicated to have it anyway.

7. To identify and avoid the saline zones of the deep aquifer during the installation of new DTWs a practical tool has been developed which helps to determine the best possible layer for the well screen. From the lab analysis and subsequent field tests during the drilling of new DTWs, it has been demonstrated that EC values of less than 60 µS/cm in slurry test produced water with good quality in terms of salinity (EC < 1600 µS/cm). Slurry conductivity tests proved to be an effective tool for avoiding saline zones in the study area and thus enhanced the success rate of installing DTWs in some of the high salinity affected Unions.

5.9.2 Social aspects

The suitability of a technology varies among the communities who use the technology. Social and cultural factors are important in the adoption, diffusion and sustainability of a technology. Rural people have developed the habit of using hand tubewell water over the last 30 years. So any change in their behavior needs a friendly approach and technology that is geared to their needs. Following social aspects should be included with the technology proposed for Manohorganj upazila.

1. Peoples' participation in every steps of planning, implementation and monitoring is prime importance. Most of the cases people are engaged during technology handing over. They are advised to take full responsibilities of the water points while they know very little about it. They don't feel the ownership and don't maintain it properly. Other than tubewell technology people does not know where to collect spare parts or whom to contact for repair. Ultimately within a very short period the technology became non-functional.

   From the household survey it has been found that VERC (NGO) installed DTWs are more well maintained (91%) than GoB DTWs (57%). Regarding O&M, users of VERC DTW are more active and less repair needed in last one year compare to GoB DTW. Moreover social acceptance is better in VERC DTW (92%) than GoB DTW (71%). This is the result of 3 years arsenic mitigation project implemented by VERC, where not only the hardware installation but also demand creation, community planning and mobilization, awareness building were the major part of the project.

   It reflects the importance of community participation in planning, implementation and monitoring for the long term sustainability.

2. Proper O&M systems should be developed for each of the water facilities. Different technology should have different modalities but trained caretaker is must for each facilities.

The maintenance is easy for suction mode DTWs and spare parts are available in local market. BUT force mode DTW – Tara II is still not common to people and spare parts are not available in the local market. This need special training to caretaker and union level mechanics to keep it functional in longer run and ensuring the supply of spare parts in local market.

Piped Water Supply System need an effective management committee and a paid caretaker. There should be a bank account managed by word commissioner and management committee for each PWSS. Each household should pay monthly according to their ability (community decided) for O&M of the system. These O&M cost incudes caretaker's salary, electricity bill, regular maintenance and periodic maintenance and repair.

Household based Rainwater Harvesting System need proper orientation regarding the collection and preservation of water maintaining the highest level of hygiene and the effective use of water. From Water quality survey it has been found that 6 out of 15 have faecal coliform more than 10/ 100ml. Not only orientation, proper monitoring and follow up is needed whether they are following the roof cleaning and first flush rule properly and end cap is open during normal time. During survey, in 3 household end cap was found attached with pipe which can easily contaminate the storage water with sudden rain. Cleanliness of roof and storage tank is critical to maintaining good quality of water.

Solar Water Purifier or other Arsenic removal technologies need proper orientation of technologies, spare parts available in the local market and relevant skill mechanics to fix it. Proper monitoring and follow up is necessary from the agency or government after the end of project completion.

3. Awareness raising activities: Strong awareness on arsenic issues and its impact on health need to be developed among the people, so that they understand the importance of having arsenic safe technology, own the technology, maintain it properly and keep it operational. From the household survey it has been found that 91% people know

that drinking arsenic contaminated water is harmful for health but 69% are agreed to go far to collect arsenic safe water in case of non-availability of arsenic safe water nearby. Only 50% knows where to go when arsenicosis symptoms observed.

Different tools and technics should be used for awareness raising activities on arsenic issues. It includes courtyard session at community level, tea stall session, child group session, classroom session and essay competition at schools, drama, rally, wall painting, billboard, etc. The print and electronic media also can play a vital role of raising arsenic awareness.

5.9.3 Economic Aspects

When predicting the costs for arsenic mitigation over a future time period it is important to acknowledge the hydrogeology and water chemistry trends of that area. From economic aspects, Deep Tubewell (suction mode) is the most cost effective among other technologies. But this area have low water table for the standard #6 hand pump and requiring more expensive force mode pump. Multiple connection tubewells will also not be feasible for this area anymore. Moreover, Piped Water Supply Scheme without treatment plant will not be sustainable or feasible due to high iron and manganese. Treatment plant will make the cost almost double.

Rainwater Harvesting (RWH) could be promoted to serve small and more isolated families, though it is more expensive and requires considerable maintenance.

Solar Water Purifier or Solar Distillation Panels, a major innovation for water scarce area, may be applicable at least for isolated pockets of exposure and perhaps more widely where both aquifers have water quality problems. As a household solution, it appears comparable in cost to rainwater harvesting.

Though cost is a factor, but selection of appropriate and safe arsenic mitigation technologies are prime important. From a UNICEF study, the estimated economic losses due to arsenic exposure in drinking water at current levels are at least 10 times of the costs providing complete safe water coverage to the exposed population in Comilla. Thus, the selection of appropriate safe –water technologies will depend on hydrogeological conditions, public health risks and social acceptability by the community. Cost is an important factor but it should not limit the scope of appropriate technology selection.

Thus, Table 5-8 describes union wise recommended technologies considering the overall findings of the study that includes; aquifer characteristics, static water table in shallow and deep tubewells, water quality problems and peoples' preferences of existing technologies. The major deviation is existing most popular suction mode DTWs and multiple connections will no longer be feasible due to lowering of water table. Force mode DTWs could replace the suction mode DTWs. Exploring intermediate depths of Aquifer and new technology piloting such as Managed Aquifer Recharge are came as potential technology choice.

Table 5-8: Water Supply Technologies Recommendation Matrix

District	Upazila	Union	Present Aquifer	Static Water Table, May 2013 in Feet		Water Quality Problems							Average depth of Tube well in Feet		Existing technology performance ranking/ preferred Technologies	Water Supply Technology Selection / Recommendations based on Aquifer Charecterstics, Water Quality, Water Table and peolpe's preference **Multiple Connections and suction mode DTWs will not be suitable anymore due to lowering of Water Table in all unions					Remarks
						% As Contamination in STWs	Fe Problem (>5 ppm) Yes/No		Mn Problem (>0.04 ppm) Yes/No		Cl Problem (>600 ppm) Yes/No										
				STW	DTW		STW	DTW	STW	DTW	STW	DTW	STW	DTW		1	2	3	4	5	
Comilla	Manoharganj	Baishgaon	A1= 80-220 A2= 280-710	8	22.5	98.8	No	No	-	No	No	No	100	700	1st - Multiple Connections attached with DTW	DTW - Tara II (force mode)	PWSS with Iron Removal Plant (IRP)	RWHs			Lowering WT Iron is more than 1.0 mg/l but less than 5.0 mg/l
Comilla	Manoharganj	Bipulasar	A1= 40-300 A2= 380-480 A3= 500- 750	10	23	96.88	No	Yes	-	Yes	No	Yes	90	800	2nd- DTWs-#6 (sunction mode)	Explore Intermidiate depth (Aquifer	DTW - Tara II with slurry EC test as precaution	PWSS with Treatment Plant	Managed Aquifer Recharge	RWHs/ SWP/ART	Lowering WT. Fe, Mn and Cl Problem
Comilla	Manoharganj	Hasnabad	A1= 30-410 A2= 500-640	10	22	99.41	No	Yes	-	Yes	No	Yes	80	700	3rd- Piped Water Supply System (PWSS)	DTW - Tara II with slurry EC test as precaution	PWSS with Treatment Plant	Managed Aquifer Recharge (MAR)	RWHs	SWP/ART	Lowering WT. Fe, Mn and Cl Problem
Comilla	Manoharganj	Jhalam (N)	A1= 40-220 A2= 260-700	11	35	98.52	No	Yes	-	No	No	No	50	700	4th- Rain Water Harvesting System (RWHs)	DTW - Tara II with IRP	PWSS with Iron Removal Plant (IRP)	RWHs	SWP/ART		Lowering WT and Fe Problem
Comilla	Manoharganj	Jhalam (S)	A1= 60-200 A2= 300-700	13	24.5	99.43	No	Yes	-	No	No	No	50	700	5th - Solar Water Purifier (SWP) / Arsenic removal Technologies (ARTs)	DTW - Tara II with IRP	PWSS with Iron Removal Plant (IRP)	RWHs	SWP/ART		Lowering WT and Fe Problem
Comilla	Manoharganj	Khila	A1= 90-180 A2= 210-430 A3= 490- 780	10.5	22	99.15	No	Yes	-	Yes	No	Yes	80	800		Explore Intermidiate depth (Aquifer	DTW - Tara II with slurry EC test as precaution	PWSS with Treatment Plant	Managed Aquifer Recharge	RWHs/ SWP/ART	Lowering WT. Fe, Mn and Cl Problem
Comilla	Manoharganj	Laxmanpur	A1= 40-220 A2= 360-460 A3= 520- 680	12	22	98.68	No	Yes	-	Yes	No	No	50	700		Explore Intermidiate depth (Aquifer A2)	PWSS with Iron Removal Plant (IRP)	DTW - Tara II with IRP	RWHs	SWP/ART	Lowering WT Fe and Mn Problem
Comilla	Manoharganj	Moishtua	A1= 20-250 A2= 300-480 A3= 530- 700	15	27	99.13	No	No	-	No	No	No	70	700		DTW - Tara II (force mode)	PWSS	RWHs			Lowering WT
Comilla	Manoharganj	Natherpetu	A1= 100-510 A2= 590-750	21	25	99.35	No	Yes	-	Yes	No	Yes	50	750		PWSS with Treatment Plant	DTW - Tara II with slurry EC test as precaution	Managed Aquifer Recharge (MAR)	RWHs	SWP/ART	Lowering WT. Fe, Mn and Cl Problem
Comilla	Manoharganj	Swaraspur	A1= 20-250 A2= 270-660	15	22	99.09	No	Yes	-	No	No	No	80	660		PWSS with Iron Removal Plant (IRP)	DTW - Tara II with IRP	RWHs	SWP/ART		Lowering WT Fe and Mn Problem
Comilla	Manoharganj	Uttar Howla	A1= 80-220 A2= 300-420 A3= 500- 700	12	23	98.5	No	Yes	-	Yes	No	Yes	50	800		Explore Intermidiate depth (Aquifer A2)	PWSS with Treatment Plant	DTW - Tara II with slurry EC test as precaution	Managed Aquifer Recharge (MAR)	RWHs/SWP/ART	Lowering WT. Fe, Mn and Cl Problem

Note: Managed Aquifer Recharge (MAR) technology is a recent innovative technology promoted in saline prone coastal areas of Bangladesh by UNICEF/DPHE/DU.

CHAPTER 6 : CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study area, Manohorganj Upazila of Comilla district, is located in the middle southeastern part of Bangladesh include 11 severely As contaminated unions where 98.8% of the STWs yield water with As concentration above 50 µg/L. Moreover, scarcity of other safe water options (< 20%) made this Upazila a very high priority area for developing alternative safe water options.

A detail Water Quality analysis in deep aquifer has been done and spatial map has been produced for better understanding. From the analysis it has been found that iron, manganese and chloride are major problems in deep aquifer.

According to the study, higher EC value (EC> 800 µS/cm) has been observed in the south eastern, eastern and western part of the study area comprising Natherpetua, Bipulasar, Hasnabad and Khila unions and also gives an indication of overall water quality condition. Iron is higher than Bangladesh standards (1.00 mg/L) almost in all 11 unions. High manganese is also observed in some unions. The spatial distribution of Manganese in the study area shows that south eastern, eastern and western part of the study area including Khila, Uttar Hawla, Natherpetua, Bipulasar and Hasnabad union have Mn value higher than 0.4 mg/L (WHO guideline value).

A combined water quality map has been produced for iron, manganese and chloride and found that Khila, Uttar Hawla, Natherpetua, Bipulasar and Hasnabad unions are mostly contaminated and under risk of these water quality problems.

From the bore logs data, the subsurface geological conditions of the study area have been described. Lithologic and hydrostratigraphic cross sections and models reveal that the study area consists of six unit hydrostratigraphic system with three aquifers and three aquitards. Presence of one thick aquitard (aquitard-2) with the thickness of 30-80 feet separates the deep aquifers from the As contaminated shallow aquifer. Two distinct deep aquifers (aquifer-2 and aquifer- 3) are present in the southern and eastern portion of the study area while the northern and western portion is characterised by a one thick deep aquifer. Lithologically all the aquifers are characterised by medium to fine grained sands.

The water table map shows the huge variation in static water levels in Shallow and Deep wells. In Shallow Tubewells water levels are still in suction limit, ranges from 8- 15ft below ground level. But in Deep Tubewells the static water levels were mostly beyond suction limit ranges from 20 -35ft below ground level. The time line variation graph shows the decreasing trend of water level in recent years from 2000.

Slurry tests were conducted in the field during the installation of new DTWs. EC values of less than 60 μS/cm in slurry test produced water with good quality (EC < 1600 μS/cm).

From household survey on existing technology performance, has been found that Deep Tubewell (suction mode) and multiple connection are the preferred technology among others. This is due to the availability of water all the time, easy to operate, cost effectiveness, easy O&M, available spare parts and finally the habituation of the tubewell technology. Next preference is Piped Water Supply System (PWSS). The reason behind not being 1st preference is intermittent water supply and the piped supply. People think that though it is underground water, they are not getting it directly, it comes through pipe network. It is not cool or taste not like tubewell water. Rainwater Harvesting System become the 3rd or 4th choice of people due to not getting enough water whole the year round, flat taste, Operation and Maintenance is not easy and repairmen take time. Last choice but not the least is other arsenic removal and treatment units.

Source water quality has been tested for surveyed households that also revealed the people's perception on technologies. The major problem encountered was iron that affects the taste and smell and use of water.

Considering the hydrogeological context, hydro stratigraphy of the aquifer, water quality and water table situation and people's opinion a number of technologies recommended for future planning and interventions. Major technologies recommended are 1. DTWs (Tara II) with slurry EC test with precaution, 2. Exploring intermediate depth in few unions, 3.

Piped water supply system with treatment plant, 4. Rainwater Harvesting Systems at isolated households, 5. Managed Aquifer Recharge (MAR) System. A GIS map of all safe water technologies has been developed to identify the future need through pin pointing the population still uncovered by safe and sustainable water technologies.

Now the urgent action is needed to re-focus the attention of the government and NGOs to provide extensive support to Manohorganj Upazila. The support from government and NGOs are not enough and the safe water coverage is still less than 40%. Huge number of people are in dire need of arsenic safe water. Extensive support is required in this upazila on arsenic monitoring, mitigation and patient management.

6.2 Recommendations

Based on the results and findings of the current study, following recommendations are put forward for ensuring sustainable supply of safe water in Manohorganj Upazila:

- A holistic approach of arsenic mitigation is a crucial need to address severely arsenic affected population of Manohorganj Upazila
- Deep Tubewells (more than 150m depth) with force mode pump should replace the Deep tubewells with # 6 pump due to lowering of water table
- Further investigation is necessary to explore the intermediate aquifer in southern and south- east part of the upazila for observing water quality parameters comply with Bangladesh Standards
- Piped water supply system should be provided with careful investigation of ground water quality to avoid future risk of arsenic and salinity.
- Iron and manganese are the major problems in promoting piped water supply systems. Treatment plant should be considered when designing piped water schemes.
- Rainwater Harvesting systems should be promoted only for remote and isolated families who could not be connected to Deep Tubewells or piped water schemes
- Installation of irrigation well in deep aquifer is discouraged for the sustainability of long-term drinking water supply.
- Slurry conductivity test should be conducted with great care during the installation of every new DTW to avoid the saline zones.

- Post project monitoring and follow up support is necessary for certain period of time (at least at lower profile), to observe and provide technical support to communities in managing the water points without any external support.
- DPHE should play the role of periodic water quality monitoring of deep aquifer to see the trend especially for arsenic and salinity.
- Arsenicosis patient identification and surveillance is very important for this upazila. Government and NGOs should take necessary steps as soon as possible.

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Annex 1: Model of Constructed Bore Log Records

GPS	23.143900,91.06093333	Drilling Duration	30/01/2012 to 04/02/2012
District	Comilla	Drilling Depth	780'
Upazila	Manohorganj	Well Depth	775'
Village/Union	Latsar/Khila	Screen Length	20'
Well ID	**DTW 001**	Well Diameter	1.5"
Owner's Name		Borehole Diameter	4"

Depth (ft)		**Lithologic Description**	**Field Colour**	**EC (µS/cm)**
From	To			
0	30	Silty Clay	Dark Grey	46
30	60	Silt	Grey	20
60	90	Silt	Grey	27
90	120	Fine Sand	Light Grey	24.5
120	150	Fine Sand	Light Grey	25
150	180	Fine Sand	Light Grey	27
180	210	Silty Clay	Dark Grey	26
210	240	Fine Sand	Grey	27
240	270	Fine Sand	Grey	27.2
270	300	Silt	Dark Grey	45
300	310	Silt	Dark Grey	31
310	320	Fine Sand	grey	31
320	330	Fine Sand	Grey	35
330	340	Fine to Medium Sand	Grey	36
340	350	Fine to Medium Sand	Grey	
350	360	Fine to Medium Sand	Grey	
360	370	Fine Sand	Light Grey	28
370	380	Fine Sand	Grey	21
380	390	Fine Sand	Grey	27.2
390	400	Fine to Medium Sand	Grey	33
400	410	Fine to Medium Sand	Grey	33
410	420	Fine to Medium Sand	Grey	36
420	430	Fine Sand	Grey	39
430	440	Silty Clay	Dark Grey	43
440	450	Silty Clay	Dark Grey	42
450	460	Silty Clay	Dark Grey	38
460	470	Silty Clay	Light Grey	40
470	480	Silty Clay	Dark Grey	42
480	490	Silty Clay	Dark Grey	48
490	500	Very fine Sand	Dark Grey	44
500	510	Fine to Medium Sand	Light Grey	46
510	520	Fine to Medium Sand	Grey	30
520	530	Fine to Medium Sand	Grey	34
530	540	Fine Sand	Grey	34
540	550	Fine Sand	Grey	40
550	560	Fine to Medium Sand	Light Grey	34
560	570	Fine Sand	Grey	37
570	580	Silt	Grey	39
580	590	Silt	Grey	38

GPS	23.143900,91.06093333	Drilling Duration	30/01/2012 to 04/02/2012
District	Comilla	Drilling Depth	780'
Upazila	Manohorganj	Well Depth	775'
Village/Union	Latsar/Khila	Screen Length	20'
Well ID	**DTW 001**	Well Diameter	1.5"
Owner's Name		Borehole Diameter	4"

Depth (ft)		**Lithologic Description**	**Field Colour**	**EC (µS/cm)**
From	To			
590	600	Medium to Fine Sand	Grey	31
600	610	Medium to Fine Sand	Grey	25
610	620	Fine Sand	Light Grey	21
620	630	Medium Sand	Grey	35
630	640	Fine to Medium Sand	Light Grey	14
640	650	Medium to Fine Sand	Light Grey	17
650	660	Medium to Fine Sand	Light Grey	12
660	670	Medium to Fine Sand	Light Grey	17
670	680	Medium to Fine Sand	Light Grey	12.5
680	690	Medium to Fine Sand	Light Grey	11.5
690	700	Medium to Fine Sand	Light Grey	11.5
700	710	Medium to Fine Sand	Light Grey	19
710	720	Medium to Fine Sand	Light Grey	22
720	730	Medium to Fine Sand	Light Grey	16
730	740	Medium to Fine Sand	Light Grey	15
740	750	Medium Sand	Light Grey	17
750	760	Medium Sand	Light Grey	16.5
760	770	Medium Sand	Light Grey	22
770	780	Medium to Fine Sand	Light Grey	21.6

Annex 2: 117 water quality tests from EWAG Lab

Location : Monohargonj, Comilla.

Information of water sample for lab test

sent by Nargis Akter by FedEx from Dhaka on 24Oct 2012

arrived at Eawag on 28Oct2012 and analyzed by ICP-MS and IC in November and December 2012

Concentratoin of Elements measured with ICP-MS at Eawag (means + dilution correction (+3%))

SL #	Owner/ Caretaker's Name	Provided by	Village/ Community	Union	Depth	Installation	Ward #	Sample	Eawag Nr.	Na / 23 [#2] mg/L	Mg / 24 [#2] mg/L	Cl / 35 [#2] mg/L	K / 39 [#2] mg/L	Ca / 44 [#2] mg/L	Mn / 55 [#2] µg/L	Fe / 56 [#2] mg/L	As / 75 [#2] µg/L	Fluoride mg/l
1	Anowarul Azim	DPHE	Chiktia	Jhalam Uttor	650	2009	2	JU 1	52	59	41	206	4.9	67	242	6.0	1	0.1519
2	Mizanur Rahman	DPHE	Noagaon	Jhalam Uttor	750	2004	3	JU 2	53	21	17	20	3.1	26	107	2.4	1	0.21
3	Ali Miah	NGO Forum	Lalchandpur	Jhalam Uttor	702	2009	3	JU 3	54	20	12	0	2.6	21	71	1.7	1	0.3506
4	Abul Khaer Chowdary	DPHE	Debpur	Jhalam Uttor	700	2005	6	JU 4	55	25	14	31	2.8	29	88	3.2	1	0.2221
5	Mizanur Rahman	DPHE	Doiara	Jhalam Uttor	800	2007	7	JU 5	56	20	12	1	2.7	20	83	2.1	1	0.2437
6	Md. Momotaj	DPHE	Haria Hosenpur	Jhalam Uttor	750	2008	7	JU 6	57	36	13	28	2.9	22	75	2.3	1	0.2354
7	Shree Uttom Deb	DPHE	Dikchanda	Jhalam Uttor	700	2005	8	JU 7	58	21	13	7	2.6	20	86	2.2	1	0.2591
8	Hosneara Member	NGO Forum	Boro keshtola	Jhalam Uttor	850	2008	9	JU 8	59	20	13	-1	2.6	22	86	2.2	1	0.2487
8	Hosneara Member	NGO Forum	Boro keshtola	Jhalam Uttor	850	2008	9	JU 8	60	20	13	-1	2.7	22	87	2.3	1	0.2449
9	Choraish Primary school	DPHE	Choraish	Jhalam Uttor	650	2008	5	JU 9	61	28	16	32	2.4	30	120	4.2	1	0.2439
10	Setara Begum	DPHE	Banglaish	Jhalam Uttor	705	2006	1	JU 10	62	29	28	93	4.2	43	172	3.5	1	0.1583
11	Mahabub	DPHE	Chonua	Jhalam Uttor	690	2004	4	JU 11	63	20	14	0	2.8	21	81	1.8	1	0.3148
12	Abdus Salam	DPHE	Gobindapur	Jhalam Uttor	700	2007	5	JU 12	64	25	20	40	3.2	27	125	2.3	1	0.1941
13	Pumgaon high school	DPHE	Pumgaon	Jhalam Daxin	700	1999	4	JD 1	2	20	13	23	2.7	25	85	2.4	1	0.2466
14	Jasimuddin	NGO Forum	Pumgaon Daxin	Jhalam Daxin	760	2009	5	JD 2	3	24	15	36	2.5	29	116	3.0	1	0.2672
15	Kawtola Keshtola Govt. Pri. school	DPHE	Kawtola	Jhalam Daxin	900	1994	6	JD 3	4	21	14	3	2.7	20	76	1.8	1	0.2573
16	Liakot Master	DPHE	Khurua	Jhalam Daxin	690	2009	6	JD 4	5	23	15	17	2.8	22	92	2.2	1	0.2685
17	Uziullah Molla	DPHE	Satpukuria	Jhalam Daxin	720	2004	7	JD 5	6	24	13	2	2.9	20	72	1.9	1	0.2256
18	Shah Sharif Islami pre cadet	DPHE	Mirzaapur purbo	Jhalam Daxin	600	2008	8	JD 6	7	24	13	10	2.3	22	80	2.3	1	0.2295
19	Karim Hosen	DPHE	Norohoripur	Jhalam Daxin	800	2005	9	JD 7	8	33	23	73	3.2	36	169	3.4	1	0.2036
20	Abdul Latif	DPHE	Vhatgaon	Jhalam Daxin	800	2003	2	JD 8	9	56	29	154	4.1	51	211	5.8	1	0.1967
21	MMarfotullah Member	DPHE	Zadobpur	Jhalam Daxin	700	2005	3	JD 9	10	30	32	126	4.0	50	226	4.6	1	0.1819
22	Mobarok Hosen	DPHE	Lawlohori	Jhalam Daxin	700	2003	3	JD 10	11	25	14	23	2.8	26	90	2.3	1	0.3958
22	Mobarok Hosen	DPHE	Lawlohori	Jhalam Daxin	700	2003	3	JD 10	12	25	14	21	2.7	26	91	2.3	1	0.291
23	Noapara Mosque	DPHE	Noapara	Jhalam Daxin	700	2004	4	JD 11	13	20	11	6	2.6	24	90	2.3	1	0.2536
24	Kholilur Rahman	Private	Jhalam	Jhalam Daxin	750	2009	1	JD 12	14	30	22	64	3.5	29	115	3.5	1	0.2364
25	Zohirul Islam	DPHE	Paranpur	Natherpetua	700	2004	2	N 1	80	36	30	180	4.3	74	342	6.6	-1	0.2234
26	Nazrul Islam	DPHE	Paranpur	Natherpetua	750	2004	2	N 2	81	89	54	357	5.7	96	273	8.7	-1	0.1957
27	Nitish Roy	DPHE	Natherpetua	Natherpetua	655	2010	1	N 3	82	615	82	1230	10.2	108	554	8.9	-1	0.2352
28	Zahangir	DPHE	Natherpetua Madras	Natherpetua	620	2010	1	N 4	83	1719	204	3335	23.5	137	1013	10.1	-1	0.1406
29	Mohiuddin	DPHE	Binoyghor	Natherpetua	625	2008	5	N 5	84	287	66	674	5.6	89	470	9.6	-1	0.2779
29	Mohiuddin	DPHE	Binoyghor	Natherpetua	625	2008	5	N 5	85	298	68	698	5.8	92	490	10.0	-1	0.8231
30	Monir Ahmad	NGO	Batachow	Natherpetua	330	2009	6	N 6	86	1876	111	3265	40.3	69	328	3.4	1	0.3611
31	Mofizuddin Member	DPHE	Vogai	Natherpetua	700	2009	7	N 7	87	256	59	709	5.8	138	432	11.6	-1	0.1982
32	Sirajul Islam	DPHE	Bakra	Bipulasar	655	2003	9	Bi 1	88	31	27	116	3.4	39	170	4.4	-1	0.2424
33	Baitulfala Jame Mosque	DPHE	Saikchail	Bipulasar	720	2004	9	Bi 2	89	33	18	112	3.0	48	272	5.3	0	0.2222
34	Saikchail madhya para Mosque	DPHE	Saikchail	Bipulasar	800	2004	8	Bi 3	90	32	19	117	3.1	52	300	5.5	0	0.209
35	Dr. Salauddin	DPHE	Saikchail	Bipulasar	750	2004	8	Bi 4	91	39	20	143	3.1	57	361	6.0	0	0.2143
36	Khadem Ali	DPHE	Bihora	Bipulasar	620	2004	6	Bi 5	92	74	33	216	4.6	63	269	6.2	-1	0.1994
36	Khadem Ali	DPHE	Bihora	Bipulasar	620	2004	6	Bi 5	93	71	32	209	4.6	61	258	6.1	-1	0.2024
37	Kachi govt. primary school	DPHE	Kachi	Bipulasar	700	2007	4	Bi 6	94	350	61	748	7.1	91	454	11.8	-1	0.1699
38	Abdul Latif Mia	DPHE	Shikchil	Khila	620	2010	5	K 1	39	71	29	174	4.2	57	177	5.8	2	0.1981
39	Emdadul Haque	DPHE	Latshor	Khila	740	2005	8	K 2	40	91	38	252	5.7	65	231	7.0	1	0.1743
40	Abul Kalam Azad	DPHE	Dishabond	Khila	640	2001	8	K 3	41	43	64	317	6.0	103	441	11.2	1	0.1471
41	Nurul Amin	DPHE	Dishabond	Khila	780	2004	7	K 4	42	38	23	86	3.8	36	140	4.0	1	0.2252
42	Monjur Alam	DPHE	Dishabond	Khila	600	2009	7	K 5	43	29	22	66	3.8	36	140	4.4	1	0.2371
43	Amir Hosen	DPHE	Dishabond	Khila	740	2010	7	K 6	44	72	20	117	3.8	32	125	3.5	1	0.2362
44	Foez Shikder	DPHE	Taherpur	Khila	760	2001	6	K 7	45	34	34	139	4.2	54	181	5.1	1	0.1989
45	Upazila Parishad	DPHE	Dishabond	Khila	720	2010	8	K 8	46	98	15	122	3.5	24	101	2.6	1	0.2654
46	Monohargonj high school	DPHE	Dishabond	Khila	720	2002	7	K 9	47	36	25	95	4.0	37	134	3.9	1	0.2037

										Na / 23 [#2]	Mg / 24 [#2]	Cl / 35 [#2]	K / 39 [#2]	Ca / 44 [#2]	Mn / 55 [#2]	Fe / 56 [#2]	As / 75 [#2]	Fluoride
SL #	Owner/ Caretaker's Name	Provided by	Village/ Community	Union	Depth	Installation	Ward #	Sample	Eawag Nr.	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/l
47	Shilchil Mosque	DPHE	Shikchil	Khila	650	2010	6	K 10	48	85	39	245	4.4	70	274	8.1	1	0.1665
48	Khokon Mia	DPHE	Hatiamori	Khila	800	2006	4	K 11	49	161	44	380	5.1	80	290	8.5	1	0.1633
48	Khokon Mia	DPHE	Hatiamori	Khila	800	2006	4	K 11	50	160	43	376	5.0	80	288	8.5	1	0.1676
49	Mostafa Kamal	DPHE	Thanger bum	Uttar Hawla	750	2007	2	UH 1	15	32	32	119	4.6	47	236	5.2	1	0.2231
50	Uttor Hawla high school	DPHE	Uttar Hawla	Uttar Hawla	820	2004	4	UH 2	16	26	23	83	3.5	39	133	3.7	2	0.2467
50	Uttor Hawla high school	DPHE	Uttar Hawla	Uttar Hawla	820	2004	4	UH 2	17	27	23	80	3.6	40	135	3.8	2	0.2416
51	Siddiqur Rahman	DPHE	Daxin Fenua	Uttar Hawla	800	2006	1	UH 3	18	53	26	124	4.3	46	167	4.4	1	0.247
52	Moniruzzaman	DPHE	Uttar Ullupara	Uttar Hawla	785	2009	9	UH 4	19	1205	154	2475	14.2	275	911	25.0	1	0.0996
53	Abul Hosen Buyan	DPHE	Uttar Ullupara	Uttar Hawla	900	2005	9	UH 5	20	33	27	111	3.7	43	172	4.2	1	0.2258
54	Abul Kalam Azad	DPHE	Katonupara	Uttar Hawla	780	2004	8	UH 6	21	335	38	561	6.3	61	262	7.0	1	0.2052
55	Mahabubur Rahman	DPHE	Koiar para	Uttar Hawla	640	2008	9	UH 7	22	55	27	133	4.3	40	175	5.1	1	0.2334
56	Haji Naderuzzaman	DPHE	Koiar para	Uttar Hawla	740	2008	9	UH 8	23	132	29	241	4.8	43	254	5.3	1	0.2449
57	Hatimara high school	DPHE	Hatimara	Uttar Hawla	633	2001	7	UH 9	24	1046	147	1816	35.9	68	115	8.6	59	0.4367
58	Chilua Islamia Madrasa	DPHE	Chilua	Baishgaon	700	2001	3	Ba 1	66	19	11	0	2.5	19	59	1.9	-1	0.2771
59	Burpresto Govt. primary school	DPHE	Burpresto	Baishgaon	700	2009	2	Ba 2	67	20	12	0	2.7	19	62	1.9	-1	0.2752
60	Md. Nurnobi	DPHE	Atakora	Baishgaon	750	2004	1	Ba 3	68	19	12	0	2.5	20	57	1.7	-1	0.2954
61	Md. Khokon	DPHE	Aundirpar	Baishgaon	800	2006	1	Ba 4	69	20	13	15	2.6	21	72	2.2	-1	0.2961
62	Zahangir Alam	DPHE	Pearatoli	Baishgaon	700	2005	3	Ba 5	70	19	12	0	2.4	21	71	2.2	-1	0.3388
63	Harun-or-Rashid	DPHE	Jolipur	Baishgaon	700	2005	3	Ba 6	71	19	12	14	2.7	22	81	2.2	-1	0.2744
64	Mozibul Haque	DPHE	Baishgaon Daxin	Baishgaon	750	2001	9	Ba 7	72	19	13	2	3.1	18	69	2.1	-1	0.32
65	Delour Hossen	DPHE	Baishgaon Uttar	Baishgaon	600	2009	8	Ba 8	73	65	21	134	3.3	40	117	3.5	-1	0.2272
66	Shahidullah	DPHE	Udaish	Baishgaon	720	2003	7	Ba 9	74	33	26	93	4.5	33	136	3.6	-1	0.2115
67	Golam Kibria	DPHE	Keari	Baishgaon	760	2004	7	Ba 10	75	20	13	4	3.1	18	73	2.1	-1	0.2417
68	Mofizur Rahman	DPHE	Mandargaon	Baishgaon	750	2005	6	Ba 11	76	29	25	93	3.7	35	149	4.4	-1	0.1907
68	Mofizur Rahman	DPHE	Mandargaon	Baishgaon	750	2005	6	Ba 11	77	29	25	94	3.7	35	150	4.4	-1	0.1925
69	Durgapur Govt. Parimary school	DPHE	Durgapur	Baishgaon	850	2007	5	Ba 12	78	85	29	199	4.9	43	167	4.8	-1	0.2001
70	Shah Alam member	DPHE	Hasnabad	Hasnabad	700	2003	1	H 1	26	195	11	196	4.9	12	21	1.1	1	0.3062
71	Abdullah Buyan	DPHE	Ashiadi	Hasnabad	700	2008	2	H 2	27	109	15	118	3.8	23	79	2.0	1	0.2713
72	Muklesur Rahman	DPHE	Hasnabad Bazar	Hasnabad	900	2002	1	H 3	28	137	20	188	4.5	33	127	2.8	1	0.2296
73	Shahajan Miah	DPHE	Baduara	Hasnabad	700	2004	4	H 4	29	48	44	226	6.4	76	309	6.4	1	0.158
73	Shahajan Miah	DPHE	Baduara	Hasnabad	700	2004	4	H 4	30	46	43	218	6.0	74	299	6.3	1	0.1677
74	Kustory Zahan	DPHE	Naotola	Hasnabad	700	2009	7	H 5	31	385	117	1046	11.3	194	923	14.4	1	0.1248
75	Mohammad Ali	NGO	Alinokipur	Hasnabad	700	2002	1	H 6	32	216	14	291	4.1	37	97	2.9	1	0.3042
76	Abdul Kader	DPHE	Norpaia	Hasnabad	760	2008	5	H 7	33	44	43	237	5.7	81	310	6.9	1	0.1335
77	Idrish Miah	NGO	Kasoi Mosjidbari	Hasnabad	750	2009	6	H 8	34	67	28	144	5.0	45	159	3.4	1	0.1632
78	Dilip Roy	DPHE	Monipur	Hasnabad	700	2007	8	H 9	35	61	38	192	5.3	55	198	5.3	1	0.1479
79	Sree Hore Krishno	DPHE	Komolpur	Hasnabad	750	2005	9	H 10	36	147	14	189	3.8	25	68	2.2	1	0.3045
80	Nurul Islam	NGO	Sreepur	Hasnabad	800	2008	9	H 11	37	128	28	248	4.1	57	174	4.5	1	0.1867
81	Rahman Kueti	DPHE	Niamotpur	Hasnabad	730	2005	3	H 12	38	79	16	82	4.0	22	61	2.1	1	0.2422
82	Kamaluddin	DPHE	Boro Chandpur	Sorespur	550	2008	8	SP 1	96	19	10	8	1.8	24	77	2.1	0	0.2922
83	Haji Samsul Haque	DPHE	Boro Chandpur	Sorespur	600	2009	8	SP 2	97	20	11	3	2.0	23	61	1.9	0	0.3225
84	Bangobondu Junior school	DPHE	Batabaria	Sorespur	600	2008	7	SP 3	98	20	12	0	3.0	19	51	1.8	-1	0.2756
85	Zafor Ahmed	DPHE	Dumuria	Sorespur	600	2009	9	SP 4	99	21	9	13	1.7	23	121	3.0	0	0.359
86	Mosarrof master	DPHE	Rudropur	Sorespur	850	2007	6	SP 5	100	23	10	29	2.2	26	179	3.4	0	0.2573
87	Tajul Islam	DPHE	Sorespur	Sorespur	720	2004	5	SP 6	101	20	9	0	2.2	23	99	1.9	0	0.324
87	Tajul Islam	DPHE	Sorespur	Sorespur	720	2004	5	SP 6	102	20	9	0	2.2	23	98	1.9	0	0.3168
88	Haji Lokitullah	DPHE	Alokpara	Sorespur	618	2006	4	SP 7	103	22	10	4	2.1	20	103	2.7	0	0.2648
89	Voupur govt. pri. School	DPHE	Voupur	Sorespur	650	2004	1	SP 8	104	23	20	51	3.1	28	101	2.8	0	0.2655
90	Abdul Bashar	DPHE	Shahpur	Sorespur	750	2007	3	SP 9	105	34	31	158	4.2	57	190	5.0	-1	0.1758
91	Nuru Miah	DPHE	Auchia	Sorespur	600	2009	3	SP 10	106	35	31	175	3.4	66	252	6.5	0	0.2075
92	Sakhawat Hosen	DPHE	Voupur	Sorespur	750	2009	2	SP 11	107	49	38	251	4.4	85	337	7.9	-1	0.1955
93	Helal	DPHE	Voupur	Sorespur	700	2010	1	SP 12	108	35	28	164	3.3	63	318	7.1	0	0.1987
94	Shahjahan Siraj	DPHE	Shoary	Laxmanpur	600	2010	3	LP 1	110	44	37	204	4.5	64	352	7.1	0	0.2012
95	Foazlu Miah	DPHE	Manduara	Laxmanpur	720	2007	3	LP 2	111	40	49	244	5.1	71	243	8.8	0	0.1908
96	Laxmanpur Senior Fazil Madrasha	DPHE	Laxmanpur Bazar	Laxmanpur	750	2005	2	LP 3	112	74	42	311	5.1	90	490	9.2	-1	0.1937
97	Abu Taher Kazi	DPHE	Laxmanpur uttar par	Laxmanpur	720	2005	2	LP 4	113	105	53	376	6.0	88	271	9.1	0	0.1833
98	Shahid BSc	DPHE	Betiapara	Laxmanpur	650	2004	6	LP 5	114	23	20	57	3.4	27	101	3.1	0	0.2616
98	Shahid BSc	DPHE	Betiapara	Laxmanpur	650	2004	6	LP 5	115	23	20	56	3.4	27	97	2.9	0	0.2567
99	Kharkharia govt. pri. School	DPHE	Kharkharia	Laxmanpur	620	2010	9	LP 6	116	26	25	91	3.8	33	166	4.5	0	0.2287
100	Abdul Motin	DPHE	Moraho paschim pa	Laxmanpur	600	2006	8	LP 7	117	33	38	176	4.8	53	238	5.7	-1	0.1654

SL #	Owner/ Caretaker's Name	Provided by	Village/ Community	Union	Depth	Installation	Ward #	Sample	Eawag Nr.	Na / 23 [#2]	Mg / 24 [#2]	Cl / 35 [#2]	K / 39 [#2]	Ca / 44 [#2]	Mn / 55 [#2]	Fe / 56 [#2]	As / 75 [#2]	Fluoride
										mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/l
101	Moraho Natuan Bazar	DPHE	Moraho	Laxmanpur	650	2004	7	LP 8	118	28	23	81	3.9	32	139	3.6	0	0.2561
102	Abdul Wadut	DPHE	Sopura madhya par	Laxmanpur	800	2007	4	LP 9	119	160	53	430	7.4	70	261	6.2	0	0.2013
103	Zilani member	DPHE	Betiapara	Laxmanpur	540	2009	6	LP 10	120	23	18	55	3.2	27	107	2.9	0	0.2589
104	Abu Taher	DPHE	Banghor paschim pa	Laxmanpur	650	2004	1	LP 11	121	34	36	173	4.2	57	203	5.5	1	0.1971
105	Rashid member	DPHE	Banghor	Laxmanpur	800	2004	7	LP 12	122	34	37	188	4.4	63	215	5.7	-1	0.1855
106	Amtali high school	DPHE	Amtali	Maisatua	760	2006	3	MT 1	124	35	16	50	2.9	24	80	2.3	0	0.217
107	Hajipua govt. pri. School	DPHE	Hajipura	Maisatua	700	2004	2	MT 2	125	16	13	-2	2.4	19	61	2.0	-1	0.2685
108	Ialampur govt. pri. School	DPHE	Islampur	Maisatua	700	2008	1	MT 3	126	15	11	-2	2.4	19	72	1.8	0	0.2673
109	Abdul Awal	DPHE	Nishchintopur	Maisatua	780	1998	1	MT 4	127	16	12	-3	2.4	19	63	1.9	0	0.2713
110	Ruhul Amin	DPHE	Maisatua	Maisatua	700	2006	4	MT 5	128	38	21	100	3.1	37	104	3.1	-1	0.2179
110	Ruhul Amin	DPHE	Maisatua	Maisatua	700	2006	4	MT 5	129	39	21	103	3.2	37	106	3.1	-1	0.2189
111	Shree Ranjit	DPHE	Boshowa	Maisatua	800	2004	5	MT 6	130	17	13	3	2.4	21	67	1.8	-1	0.2816
112	Haji Shamsul haque	DPHE	Merua	Maisatua	600	2007	9	MT 7	131	51	16	78	2.8	26	108	2.7	-1	0.2826
113	Shah Alam member	DPHE	Asirpar	Maisatua	1000	2003	9	MT 8	132	37	17	68	3.1	29	150	3.0	1	0.2234
114	Khanatua govt. pri. School	DPHE	Khanatua	Maisatua	800	2006	8	MT 9	133	49	15	86	2.8	32	108	3.0	0	0.2904
115	Goaliara govt. pri. School	DPHE	Goaliara	Maisatua	300	2007	7	MT 10	134	56	24	146	3.5	45	128	4.3	-1	0.2025
116	Mir Hosen	DPHE	Dumuria	Maisatua	700	2004	6	MT 11	135	23	12	34	2.7	26	114	2.5	-1	0.2127
117	Hatirpar govt. pri. School	DPHE	Hatirpar	Maisatua	700	2008	2	MT 12	136	81	28	209	3.8	48	149	4.4	0	0.1792

Annex 3: Household Level Questionnaire Survey Format

Technology Assessment Household Questionnaire Survey/খানা ভিত্তিক প্রযুক্তির গ্রহনযোগ্যতা যাচাইয়ের প্রশ্নপত্র

সিবিওর নামঃ		গ্রামের নামঃ		ওয়ার্ড নংঃ	
ইউনিয়নঃ		উপজেলাঃ		জেলাঃ	
*উত্তরপ্রদান কারীর নামঃ পুরুষ/ মহিলা (√)		পানির উৎস থেকে উত্তর প্রদান কারী খানার দূরত্বঃ (ফিট)			
ওয়াটার পয়েন্ট ID:		স্থাপনকারী সংস্থা(NGO/Govt/Private) :			
প্রযুক্তির ধরনঃ		সক্রিয় (Functional):		হ্যাঁ	না
		যদি হ্যাঁ হয়, পানির পরিমান (লি/মিনিট) (Yield (li/min)): if No, record it as non functional and skip survey যদি না হয়, তবে তথ্যটি 'সক্রিয় নয়' হিসাবে লিপিবদ্ধ করুন এবং পানির এই উৎসটি survey করা বাদ দিন			
মালিক/তত্ত্বাবধায়কের নাম : (Owner/ Caretaker Name)		ব্যাবহার কারী খানার সংখ্যাঃ		উপকারভোগী আর্সেনিক রোগীর সংখ্যাঃ	

	Technology assessment questionnaire /প্রযুক্তি যাচাইকরন প্রশ্নমালা — Score of performance	৩	২	১	মন্তব্য (উত্তর যদি ১,২,৩ নং কলামের চাইতে ভিন্ন হয় তাহলে সেটি এই কলামে লিখুন)
			(সঠিক অপশনে টিক চিহ্ন দিন)		
১.০	**ক্ষেত্র পর্যবেক্ষণ (Site Observation by surveyor)**	৩	২	১	
১.১	পানির উৎস ও আশেপাশের এলাকার পরিষ্কার - পরিচ্ছন্নতা	পরিষ্কার পরিচ্ছন্ন	সন্তোষ জনক	সন্তোষজনক নয়	
১.২	প্লাটফর্ম / পানি সংগ্রহের স্থান / বৃষ্টির পানি সংরক্ষনের ট্যাঙ্ক এর অবস্থা	ভালো অবস্থা	সন্তোষ জনক	সন্তোষজনক নয়	
১.৩	জমে থাকা/ বিদ্যমান ময়লা পানি নিষ্কাশনের সুবিধা/ ব্যবস্থা	ভালো অবস্থা	সন্তোষ জনক	সন্তোষজনক নয়	
১.৪	পানির উৎসটি নিকটবর্তী ল্যাট্রিন (নিরাপদ দূরত্ব ৩০ ফুট) ময়লা পানি বা আবর্জনা দ্বারা দুষিত হওয়ার ঝুঁকি	ঝুঁকিমুক্ত	ঝুঁকিপূর্ণ	মারাত্মক ঝুঁকিপূর্ণ	
১.৫	ব্যবহৃত পানির প্রযুক্তিটির সার্বিক কাঠামোগত অবস্থা (প্রতিটি উপাদান সচল কি না)	সব অংশই ঠিক আছে	সন্তোষ জনক	সন্তোষজনক নয়	
২.০	**খানা জরিপ- ব্যবহারকারীদের প্রযুক্তি সম্পর্কিত ধারণা (Household survey -people's perception on technology)**				
২.১	আপনিকি এই পানি পান করেন ?	হ্যাঁ	কখনও কখনও	না	যদি না হয় তা হলে এই খানায় প্রশ্ন করা বন্ধ করুন
২.২	এই পানি আপনি কি কি কাজে ব্যাবহার করেন ?	রান্না ও খাওয়ার কাজে	রান্না, খাওয়া ও গোসলের কাজে	সব কাজেই	
২.৩	সারা বছর কি এই উৎস থেকে আপনি পর্যাপ্ত পরিমান পানি পেয়ে থাকেন	হ্যাঁ	কয়েক মাস একটু কম পাই	না	
২.৪	আপনি কি রান্না ও খাওয়ার কাজে অন্য কোন উৎস থেকে পানি ব্যাবহার করেন	না	হ্যাঁ পুকুরের পানি	হ্যাঁ, নিকটবর্তী অগভীর নলকূপ	
২.৫	আপনি কত বছর যাবত এই প্রযুক্তিটি ব্যাবহার করছেন ?	২ বছরের বেশী	১ থেকে ২ বছর	১ বছরের কম	
২.৬	এই প্রযুক্তিটি আর কত সময় আপনি ব্যাবহার করতে পারবেন বলে মনে করেন	৫বছরের বেশী	৩ থেকে ৫ বছর	৩ বছরের কম	
৩.০	**খানা জরিপ - পানির গুনাগুন সম্পর্কিত ধারণা (Household survey-people's perception on WQ)**				
৩.১	এই পানির উৎসটি থেকে প্রাপ্ত পানির স্বাদ কেমন ?	ভাল	গ্রহন যোগ্য	খারাপ	
৩.২	এই পানিতে কি গন্ধজাতীয় কোন সমস্যা আছে ?	গন্ধহীন	গ্রহন যোগ্য	দুর্গন্ধযুক্ত	
৩.৩	এই পানিতে কি আয়রন বা মাঙ্গানিজ জাতীয় কোন সমস্যা আছে ?	কোন সমস্যা নাই	গ্রহন যোগ্য	গ্রহন যোগ্য নয়	
৩.৪	এই পানি্ কি লবনাক্ত ?	না	গ্রহন যোগ্য	গ্রহন যোগ্য নয়	
৩.৫	এই উৎসের পানির কি আর্সেনিক পরীক্ষা করা হয়েছে?	হ্যাঁ	জানিনা	না	
৩.৬	এই পানি্তে কি আর্সেনিক আছে?	নাই	জানিনা	আছে	
৩.৭	আর্সেনিক পরীক্ষা কতদিন আগে করা হয়েছে?	এই বছর	গতবছর	২ বছরের ও আগে	
৪.	**খানা জরিপ- সামাজিক গ্রহন যোগ্যতা (Household survey -Social acceptance)**				
৪.১	পানির প্রযুক্তিটি কি ব্যাবহার করা সহজ ?	সহজ	মোটামুটি সহজ/ সন্তোষজনক	সহজ নয়	
৪.২	আপনি কি মনে করেন বর্তমানে আপনি আগের তুলনায় (যখন অনেক দূর হতে পানি সংগ্রহ করতে হতো) কম সময়ে পানি সংগ্রহ করতে পারেন?	অনেক কম সময় লাগে	মোটামুটি কম সময় লাগে	কম সময় লাগে না	
৪.৩	পানি সংগ্রহের ক্ষেত্রে সামাজিক দ্বন্দ্ব বা অন্য কোন সমস্যার মুখোমুখি হন কিনা ?	কোন সমস্যা নেই	মাঝে মাঝে সমস্যা হয়	সামাজিক দ্বন্দ্বের কারনে বেশিরভাগ সময় সুবিধা থেকে বঞ্চিত	
৪.৪	যদি আপনার বাড়ির কাছাকাছি আর্সেনিক দূষণ মুক্ত পানি না পাওয়া যায় সে ক্ষেত্রে আপনি কতদুর থেকে খাবার পানি সংগ্রহ করতে রাজি আছেন ?	যতদূর প্রয়োজন		দূরে যেতে রাজি নই	
৫.০	**খানা জরিপ -ব্যাবহার ও রক্ষণাবেক্ষণ (Household survey- Operation & Maintenance)**				
৫.১	পানির উৎসটি কে রক্ষণাবেক্ষণ করেন ?	তত্ত্বাবধায়ক (caretaker)	জমির মালিক	নির্দিষ্ট নাই /জানি না	
৫.২	রক্ষণাবেক্ষণ কি সহজ সাধ্য ?	সহজ	মোটামুটি / সন্তোষজনক	সহজ নয়	
৫.৩	গত ১ বছরে এটি কতবার বিকল / নষ্ট হয়েছিল ?	১ বার	২-৩ বার	৩ বার বা তার অধিক	
৫.৪	ঠিক করতে কতদিন লেগেছিল ?	১-২ দিন	৩-৫ দিন	৫ দিনের বেশী	
৫.৫	পানির উৎসটির খুচরা যন্ত্রাংশ কি স্থানীয় ভাবে সহজলভ্য (পাওয়া যায়) ?	স্থানীয়ভাবে পাওয়া যায়	দূর থেকে সংগ্রহ করতে হয়	সহজলভ্য নয়	

৬.০ খানা জরীপ - অর্থনৈতিক সুবিধা (Household survey- Economic benefit)

Affordability (সামর্থ্য)

৬.১	পানির প্রযুক্তিটি স্থাপনের খরচ কেমন? (বহনযোগ্য)	সঙ্গতিপূর্ণ (reasonable)	কিছুটা ব্যায়সাপেক্ষ (little high)	উচ্চ ব্যায়সাপেক্ষ (very high)
৬.২	স্থাপন খরচের অংশ হিসাবে প্রদান করা অর্থের পরিমান কি আপনার জন্য সঙ্গতিপূর্ণ	সঙ্গতিপূর্ণ	কিছুটা ব্যায়সাপেক্ষ	উচ্চ ব্যায়সাপেক্ষ (ব্যায়বহুল)
৬.৩	ব্যাবহার ও রক্ষণাবেক্ষণ খরচ কি আপনার জন্য সহনীয়?	হ্যাঁ		না

Willing ness to pay- পানির প্রযুক্তি নির্মাণে অর্থ প্রদানে আগ্রহী

৬.৪	আপনি কি প্রযুক্তিটির নির্মাণ খরচের অংশীদারী অর্থ নিজে থেকে দিতে আগ্রহী হয়েছেন?	নিজে থেকে আগ্রহী	অন্যেরা দেয় তাই আমিও দিই	জোর করে নেয় /আগ্রহী না
৬.৫	আপনি অংশীদারী খরচ হিসাবে কততুকু অর্থ দিতে ইচ্ছুক? (যদি ৫,৪ এর উত্তর শেষের ২ টা হয়)	এখন যা দেই তার ৫0%	এখন যা দেই তার ২৫%	অর্থ দিতে ইচ্ছুক নই

৭.০ খানা জরীপ - সচেতনতার মাত্রা (Household survey- Awareness level)

৭.১	আপনি কি মনে করেন আর্সেনিক যুক্ত পানি পান করলে আপনি বা আপনার পরিবার আর্সেনিক রোগে আক্রান্ত হতে পারেন ?	জানি	কিছুটা জানি	জানি না
৭.২	আপনি আপনার গ্রামে/পরিবারে আর্সেনিক দ্বারা আক্রান্ত এমন কাউকে চেনেন ?	উত্তর হ্যাঁ হলে তার নাম ঠিকানা লিখুন-		
৭.৩	আপনি কি জানেন আর্সেনিকোসিস এর লক্ষণ দেখা দিলে চিকিৎসার জন্য কোথায় যেতে হয়?	জানি	কিছুটা জানি	জানি না
৭.৪	আর্সেনিকোসিসে আক্রান্ত রোগীর জন্য প্রয়োজনীয় ঔষধ কি সহজলভ্য?	হ্যাঁ		না
৭.৫	ঔষধ কোথা থেকে সংগ্রহ করতে হয়?	স্থানীয় ঔষধের দোকান	উপজেলা স্বাস্থ্যকেন্দ্র	জেলা ক্লিনিক/ঢাকা

৮.০ খানা জরীপ - সামাজিক সুবিধা (Household survey- Social benefit)

৮.১	আর্সেনিক দূষণ মুক্ত পানি পান করলে কি কোন স্বাস্থ্যগত সুবিধা পাওয়া যায় I (আর্সেনিকসিস রোগীর শারীরিক উন্নতি ঘটে, আর্সেনিকসিস রোগে আক্রান্ত হওয়ার ঝুকি কমে, সর্ব পরি সাস্থের উন্নতি ঘটে)	২টি উপকারিতা বলতে পারে	১ টি বলতে পারে	বলতে পারে না
৮.২	আর্সেনিক দূষণ মুক্ত পানি পান করলে কি কোন অর্থনৈতিক সুবিধা পাওয়া যায় (ঔষধের জন্য ব্যায় কমে, কার্যদিবস হারানোর ক্ষতি কম হয়, জীবন হানি কম হয়৷	অন্তত ২ টি সুবিধা বলতে পারে	অন্তত ১টি সুবিধা বলতে পারে	১ টি ও বলতে পারে না
৮.৩	আর্সেনিক দূষণ মুক্ত পানি পান করার কি কোন সামাজিক সুবিধা আছে ? (শিশুদের স্কুলে উপস্থিতি বাড়ে, সময় মত বিয়ে দেওয়া যায়, জীবন বাঁচানো যায়)।	অন্তত ২ টি সুবিধা বলতে পারে	অন্তত ১টি সুবিধা বলতে পারে	১ টি ও বলতে পারে না

উত্তর প্রদানকারীর কোন মন্তব্য যা গুরুত্বপূর্ণ সেটি লিখুন (Any Comment / note/ remarks from people not covered in the questionnaire)

নোটঃ		* কোন পরিবারে যে সদস্য পানি ব্যবস্থাপনার (পানি সংগ্রহ ও পানি ব্যবহার) সাথে সম্পৃক্ত তাকে উত্তরপ্রদান কারী (respondent) হিসাবে নির্বাচন /বাছাই করুন
	১.২	ভালো অবস্থা (Good condition) প্লাটফর্ম ভাঙ্গা না, কোন যন্ত্রাংশ ভাঙ্গা না, জলাবদ্ধতা নেই
		সন্তোষজনক (Satisfactory) প্লাটফর্ম ভাঙ্গা না, যন্ত্রাংশ ভাঙ্গা না,
		সন্তোষজনক নয় (Not Satisfactory) প্লাটফর্ম ভাঙ্গা, যন্ত্রাংশ ভাঙ্গা /ত্রুটিপূর্ণ যাতে পানি দুষিত হতে পারে৷
	১.৩	ভালো অবস্থা (Good condition) নিস্কাশন ব্যবস্থা আছে এবং সক্রিয়, ব্যবহারযোগ্য , জলাবদ্ধতা নেই৷
		সন্তোষজনক (Satisfactory) নিস্কাশন ব্যবস্থা আছে কিন্তু আংশিক সক্রিয়/ ব্যবহারযোগ্য , জলাবদ্ধতা আছে
		সন্তোষজনক নয় (Not Satisfactory) নিস্কাশন ব্যবস্থা নাই অথবা ভাঙ্গা, পুরোপুরি জলাবদ্ধ
	১.৪	ঝুকিমুক্ত (No risk) ৩০ ফুটের মধ্যে কোন ল্যাট্রিন বা ময়লা আবর্জনার স্তূপ নেই
		ঝুকির সম্ভাবনা আছে/ সম্ভাব্য ঝুকি (Possible risk) ৩০ ফুটের মধ্যে ল্যাট্রিন ও আবর্জনার স্তূপ আছে
		উচ্চ ঝুঁকি যুক্ত (High risk) খুব কাছেই ল্যাট্রিন আছে
	১.৫	ভালো অবস্থা (Good condition) পানির উৎসটি সক্রিয়, সমস্ত উপাদান (parts) ঠিক আছে
		সন্তোষজনক (Satisfactory) পানির উৎসটি সক্রিয় কিন্তু কিছু উপাদান নষ্ট বা হারিয়ে গিয়েছে
		সন্তোষজনক নয় (Not Satisfactory) পানির উৎসটি প্রায় অকার্যকর এবং অনেক উপাদান ই নষ্ট অথবা হারিয়ে গিয়েছে

Annex 4: Focus Group Discussion (FGD) Format

Checklist Questions: Interview with UP Chairman/ Upz Chairman/ SAE/ Teacher/NGO staff

Name: | Date of interview:

Designation and Address:

Their levels of concern about the arsenic problem

1. Is there a problem with arsenic here?

2. Do you consider this a serious problem? (Probe: Why, why not)

Ideas about achievements so far and present arsenic mitigation needs

1. What has been done here about the arsenic problem?

2. What more needs to be done?

Their roles in Arsenic Mitigation

1. Did you help with Asenic safe technology distribution? (Probe: how did it go? Any suggestions for future distribution approach?)

2. Were you involved in decision about the technogy site selection – where to put it?

Their knowledge about arsenic mitigation technologies

Their preferrence of technology selection considering the context and suitability(ranking)

	Technology	advantages	disadvantages
1			
2			
3			
4			

Which technology is more sustainable according to their view?

Their views on any problems associated with the technologies not selected

Future plans for arsenic mitigation

1. Will this union allocate some water and sanitation development funds to solving the arsenic problem?

2. Have there been discussions about this issue in UP meetings?

3. Is there any specific plan about funding allocation?

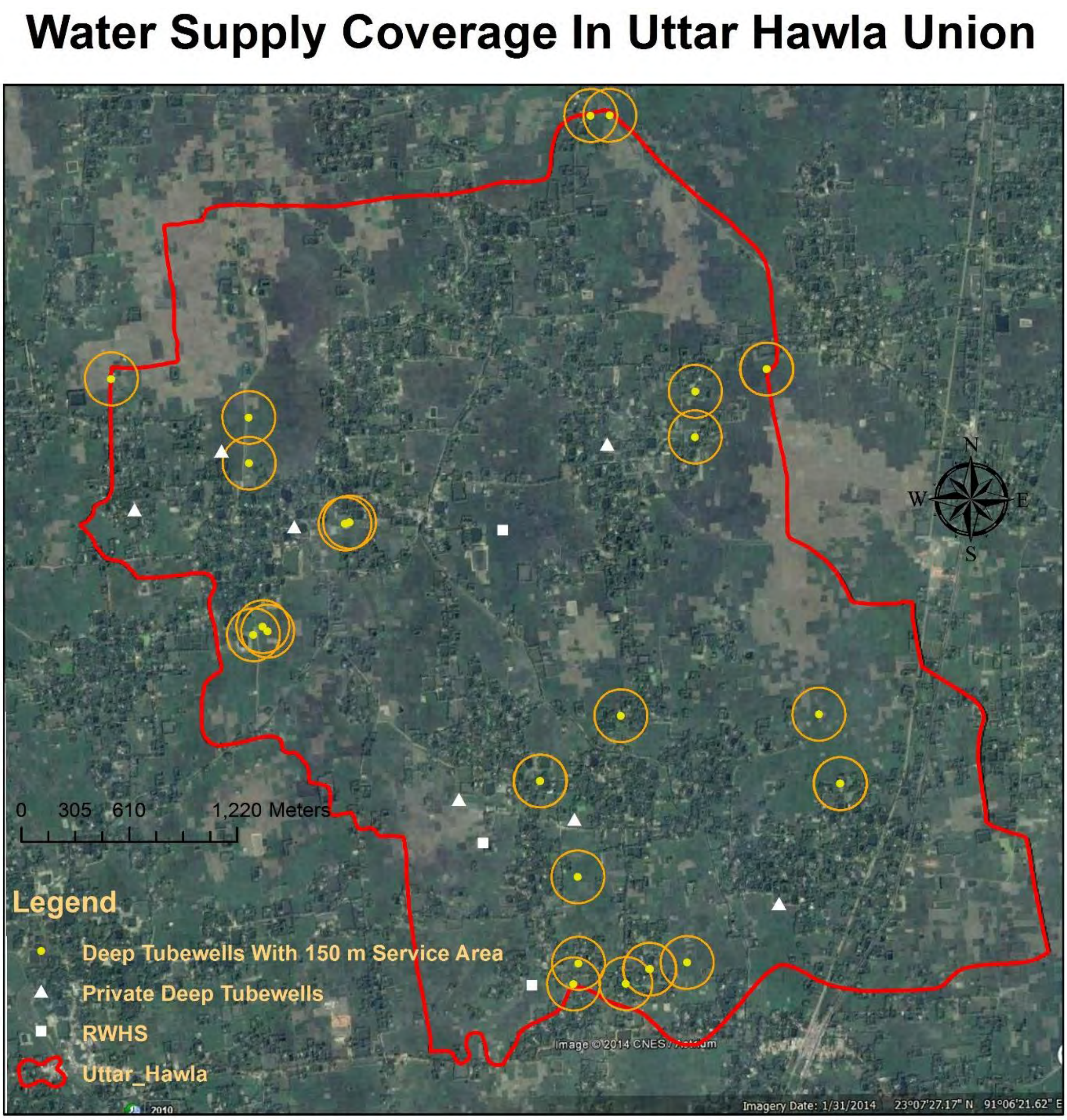
4. Is there any specific plan for arsenicosis patient?

NB: Collect WT data of last 10 years from SAE

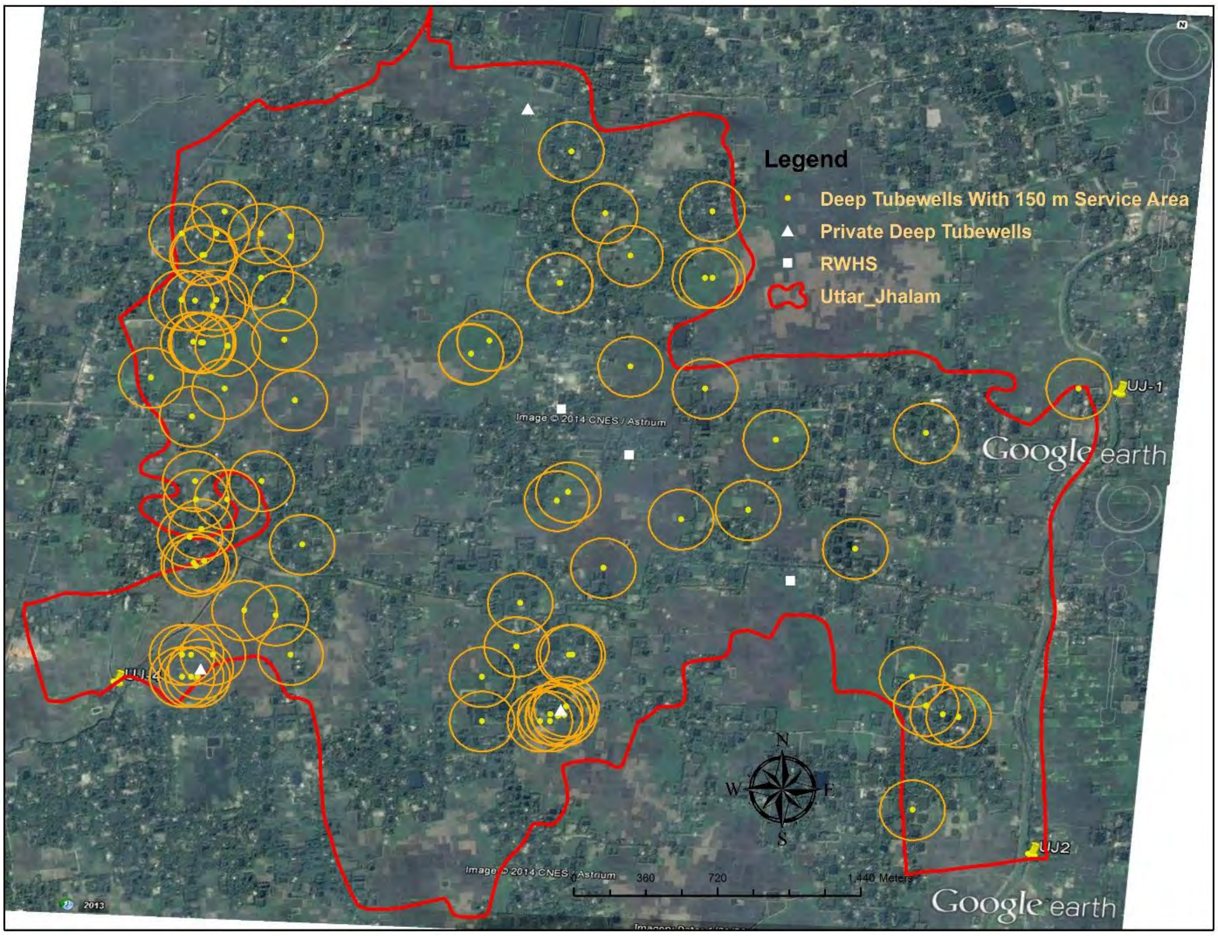
Annex-5: Water Quality Test results (BUET Laboratory)

Sl.	Union	Community	Water Collection date	Organization	Water Option	Lab ID	Arsenic (ppb) LOQ:0.001, BDS: 50	Iron (mg/L) LOQ:0.05, BDS:0.3-1	Chloride (mg/L) LOQ:5, BDS:150-600	Manganese (mg/L) LOQ:0.01, BDS:0.1
1	Khila	Dishabondho Purba Para	07-12-13	VERC	DTW	36	4	2.88	30	-0.01
2	Khila	Dishabondho Dakkhin Para	07-12-13	VERC	DTW	37	2.91	1.99	20	-0.04
3	Khila	Dishabondho Chy.Bhy. Bari-	07-12-13	VERC	DTW	38	3.03	3.06	170	0.03
4	Khila	Dishabondho Chy.Bhy. Bari-	07-12-13	VERC	DTW	39	1.08	3.97	160	0.05
5	Khila	Taherpur Dakkhin Para-1	07-12-13	VERC	DTW	40	0.74	4.78	160	0.06
6	Khila	Dishabondho Purba Shibir P	07-12-13	VERC	DTW	41	2.05	2.48	28	-0.01
7	Khila	Taherpur Dakkhin Para-2	07-12-13	VERC	DTW	42	2.22	4.87	16	0.06
8	Khila	Taherpur Purba Para	07-12-13	VERC	DTW	43	3.2	4.22	150	0.03
9	Khila	Dishabondho Saha Para	07-12-13	DPHE	DTW	44	5.03	4	145	0.05
10	Khila	Latshar Mia Bari	07-12-13	DPHE	DTW	45	8.26	7.1	335	0.12
11	Khila	Bandhuin Purba Para	07-12-13	VERC	SWP	46	1.37	-0.05	10	-0.09
13	Khila	Purba Batabaria	07-12-13	VERC	SWP	47	2.4	-0.01	9	-0.1
14	Jhalam Dakkhin	Narharipur Purba Dakkhin P	08-12-13	VERC	DTW	1	2.74	2.32	11	0.02
15	Jhalam Dakkhin	Pomgaon Pachhim Para	08-12-13	VERC	DTW	2	1.88	2.78	61	0.05
16	Jhalam Dakkhin	Keshtola Uttar Para	08-12-13	VERC	DTW	3	1.42	1.86	12	0.02
17	Jhalam Dakkhin	Jadobpur Dakkhin Para	08-12-13	VERC	DTW	4	0.57	4.88	155	0.16
18	Jhalam Dakkhin	Satpukuria Pachhim Para	08-12-13	VERC	DTW	5	4.86	1.51	10	-0.02
19	Jhalam Dakkhin	Mirzapur Uttar Para	08-12-13	VERC	DTW	6	3.54	2	23	0
20	Jhalam Dakkhin	Laulahari Pachhim para	08-12-13	VERC	DTW	7	4.23	4.49	155	0.08
21	Jhalam Dakkhin	Bochoir Uttar Para	08-12-13	VERC	DTW	8	3.83	4.09	82	0.07
22	Jhalam Dakkhin	Jhalam Dakkhin Mollah Bari	08-12-13	VERC	DTW	9	2.85	1.77	11	-0.02
23	Jhalam Dakkhin	Laulahari Dakkhin Para	08-12-13	Private	DTW	10	2.74	2.21	17	0.01
24	Jhalam Dakkhin	Pomgaon Purba Para	08-12-13	DPHE	DTW	11	2.22	4.1	96	0.07
25	Maishatua	Hatirpar Uttar Purba Para	09-12-13	VERC	DTW	15	5.72	6.73	550	-0.07
26	Maishatua	Maishatua Khamar Bari	09-12-13	VERC	DTW	16	1.2	3.22	12.5	0.02
27	Maishatua	Batabaria Dakkhin Para	09-12-13	VERC	DTW	17	5.03	3.42	103	0.06
28	Maishatua	Merua Dakkhin Para	09-12-13	VERC	DTW	18	4.17	2.62	155	0.05
29	Maishatua	Khanatua Miazi Bari	09-12-13	VERC	DTW	19	0.91	3.48	155	0.05
30	Maishatua	maishatua Dakkhin Para	09-12-13	VERC	DTW	20	0.74	2.82	69	0.01
31	Maishatua	Ashirpar Pachhim Para	09-12-13	VERC	DTW	21	3.03	3.51	68	0.06
32	Maishatua	Maishatua Mizi Bari	09-12-13	DPHE	DTW	22	6.36	4.5	330	0.04
33	Maishatua	Maishatua Uttar Moddho pa	09-12-13	DPHE	DTW	23	2.22	2.78	60	0.01
34	Maishatua	Hazi pura Pachhim Para	09-12-13	VERC	DTW	24	3.2	1.88	11	-0.01
35	Baisgaon	Baisgaon	10-12-13	VERC	PWSS	29	7.22	1.96	475	0.02
36	Hasnabad	Narpaiya	10-12-13	VERC	DTW	27	9.24	2.57	260	0.35
37	Hasnabad	Asiadari	10-12-13	VERC	DTW	28	1.54	1.16	235	-0.02
38	Baisgaon	Udaish	10-12-13	VERC	DTW	30	0.57	2.68	49	-0.02
39	Baisgaon	Baisgaon	10-12-13	VERC	DTW	31	4.75	1.72	15	0
40	Jhalam Dakkhin	Bara Jadobpur	08-12-13	VERC	DTW	12	1.88	5.18	155	0.16
41	Jhalam Uttar	Noagaon	10-12-13	VERC	DTW	13	0.74	1.56	13	-0.02
42	Jhalam Uttar	Bara Keshtola	10-12-13	VERC	DTW	14	0.74	1.97	11	0
43	Khila	Dishabondho	07-12-13	VERC	DTW	48	3.37	4.12	190	0.02
44	Saraspur	Pachruhi	11-12-13	VERC	DTW	32	2.57	3.34	94	0.03
45	Saraspur	Kismat	11-12-13	VERC	DTW	33	1.37	5.49	114	0.14
46	Maishatua	Uttar Taltola	09-12-13	VERC	DTW	25	2.68	3.12	37	0.01
47	Maishatua	Batabaria	09-12-13	VERC	DTW	26	3.08	4.81	130	0.06
48	Laxmanpur	Moraha	10-12-13	VERC	DTW	34	1.37	6.34	215	0.12
49	Laxmanpur	Kharkhoria	10-12-13	VERC	DTW	35	2.51	6.69	52	0.23

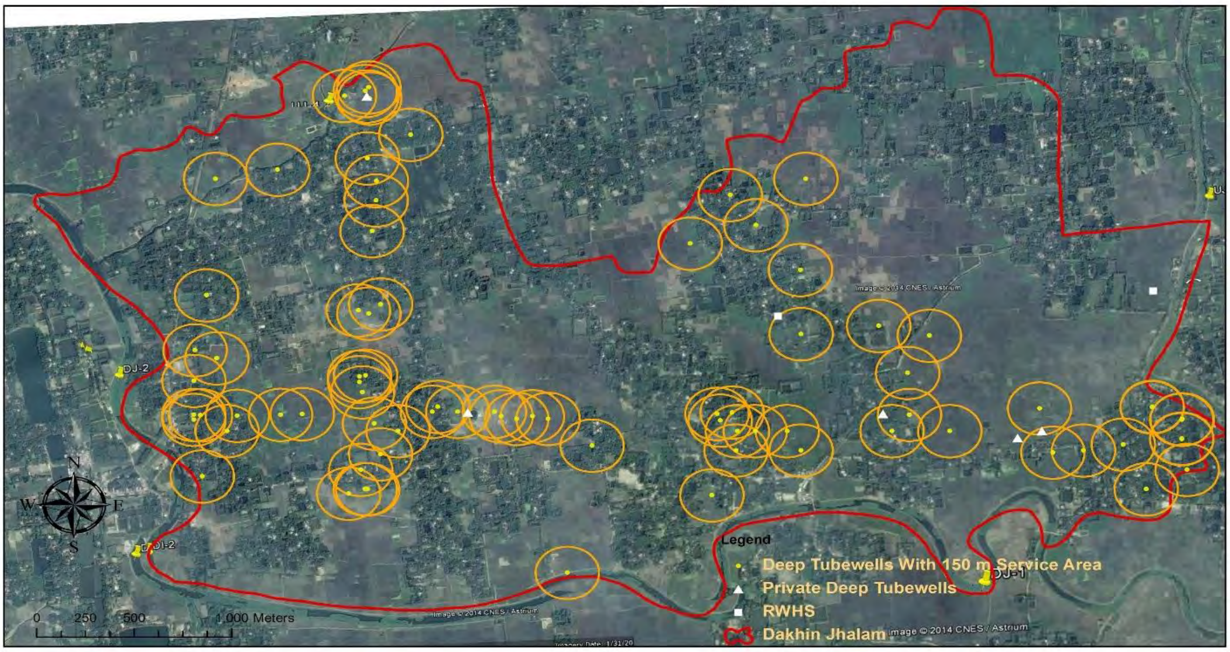
Annex-6: Union Wise Safe Water Coverage Map



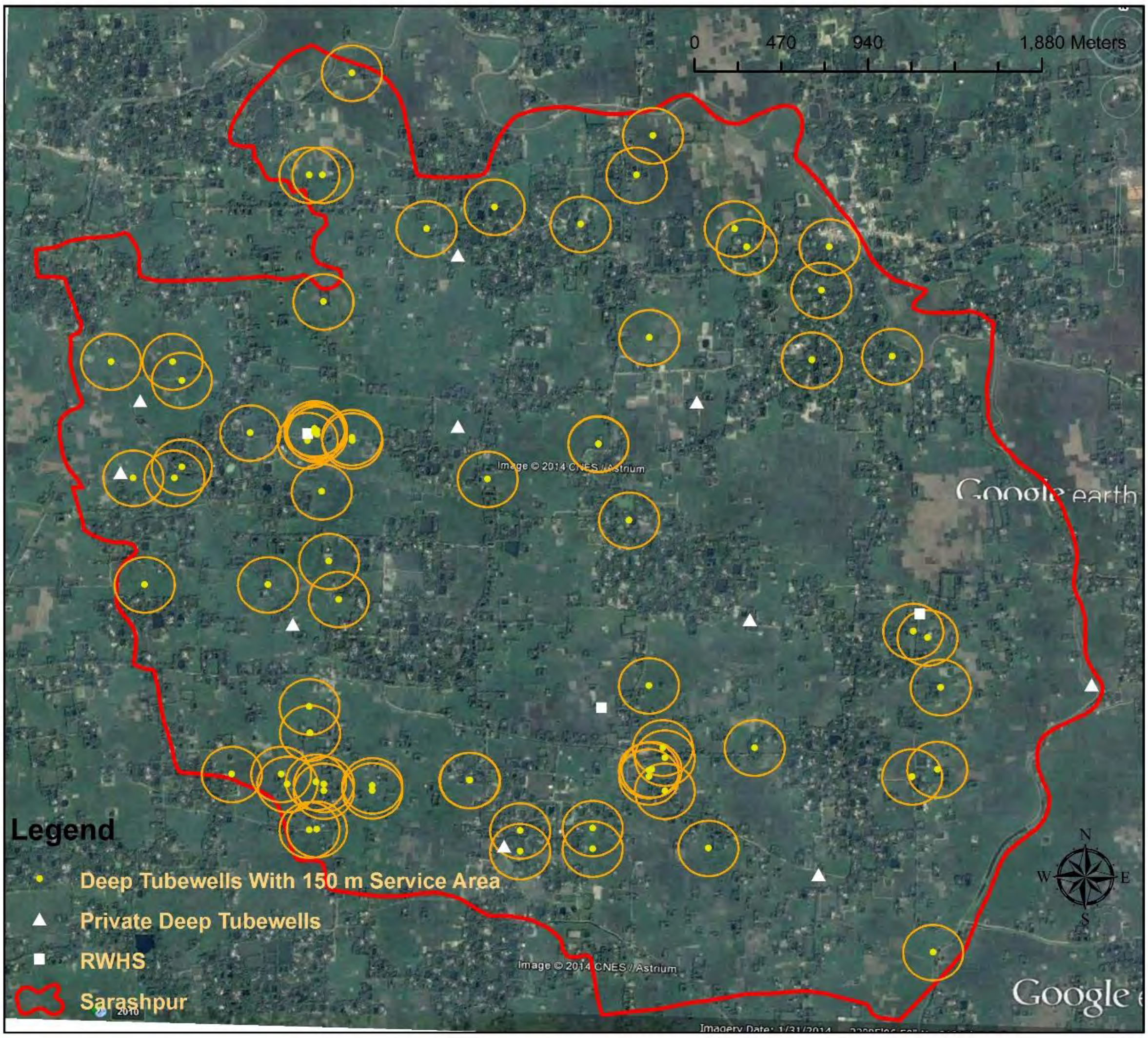
Water Supply Coverage In Uttar Jhalam Union



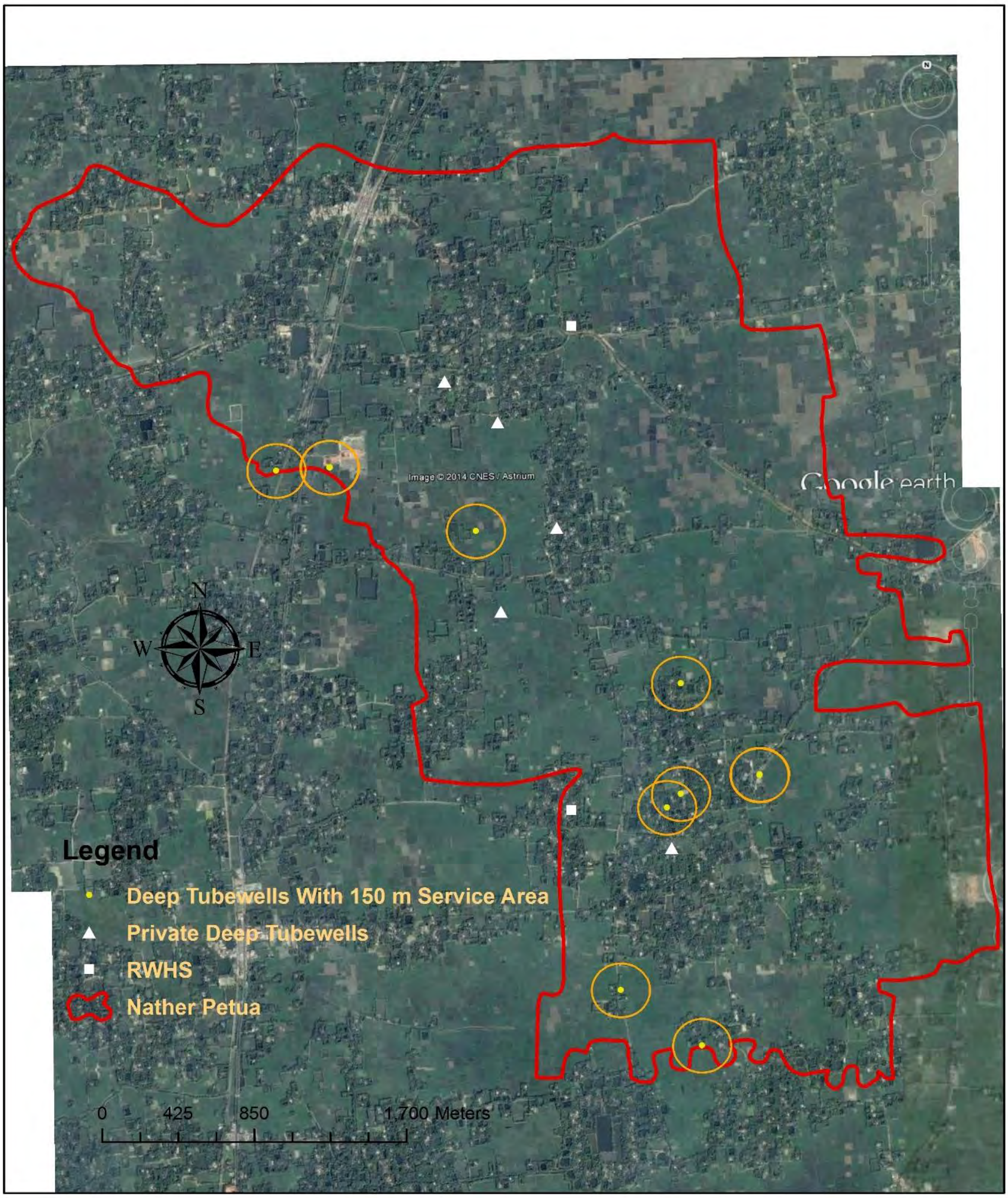
Water Supply Coverage in Dakhin Jhalam Union



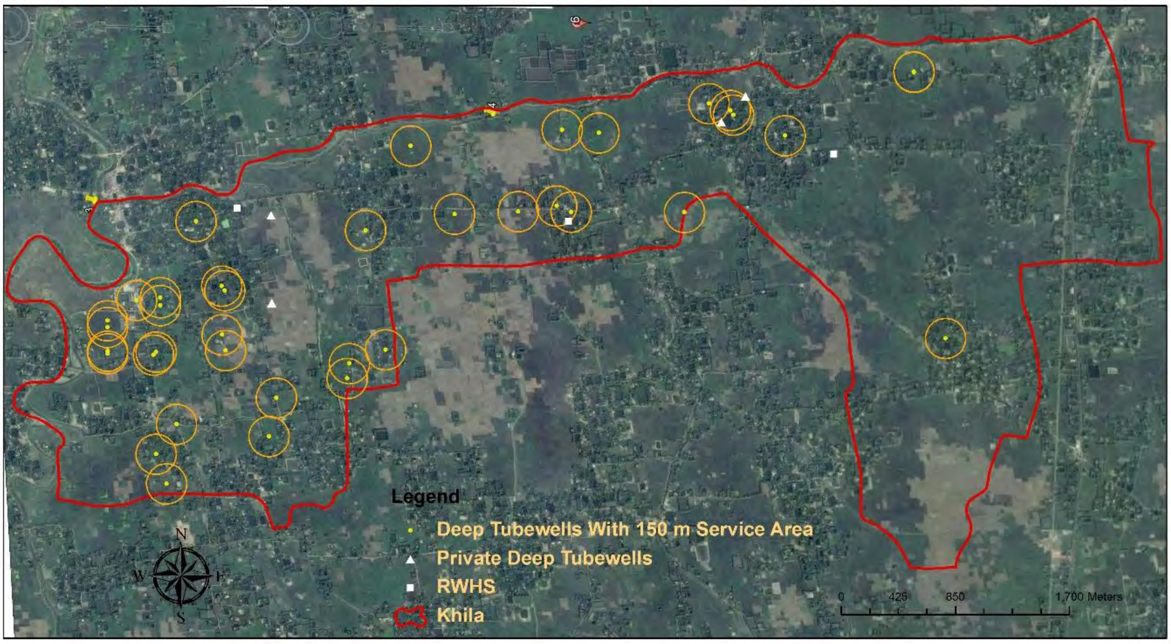
Water Supply Coverage In Sarashpur Union



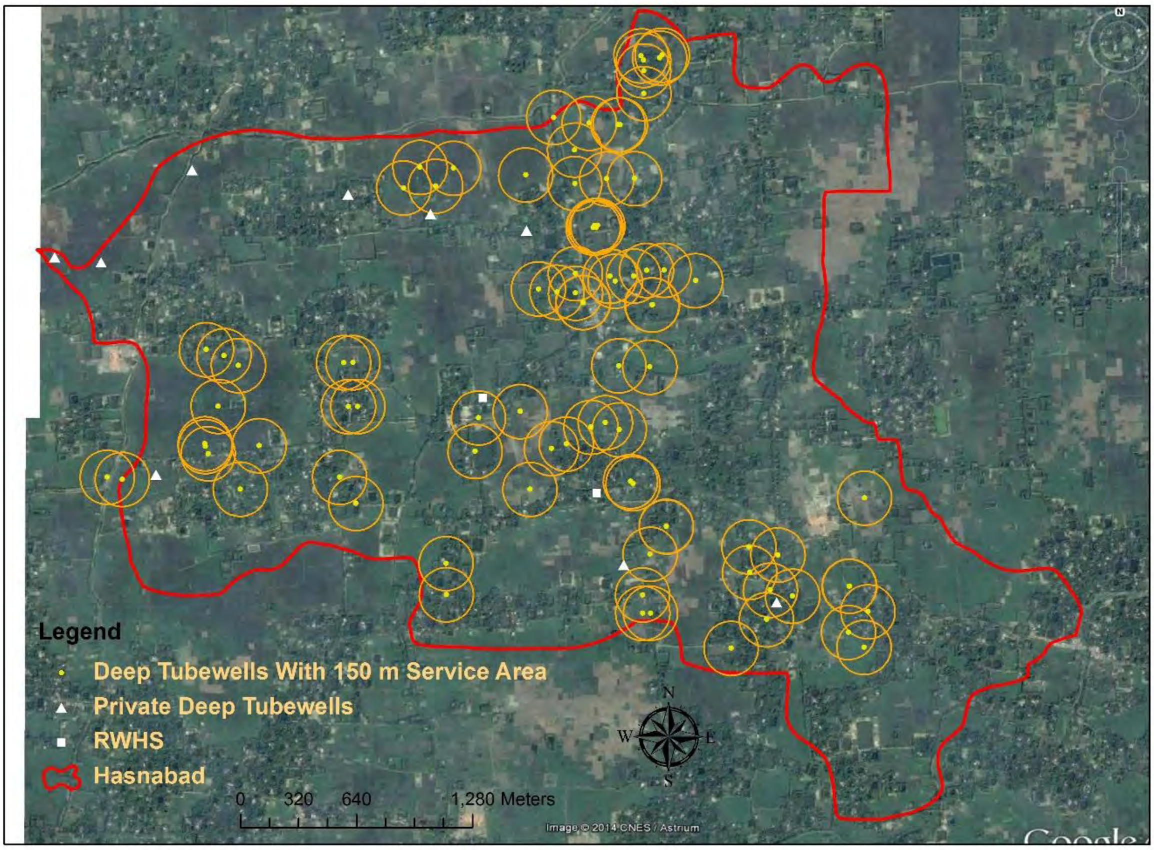
Water Supply Coverage In Natherpetua Union



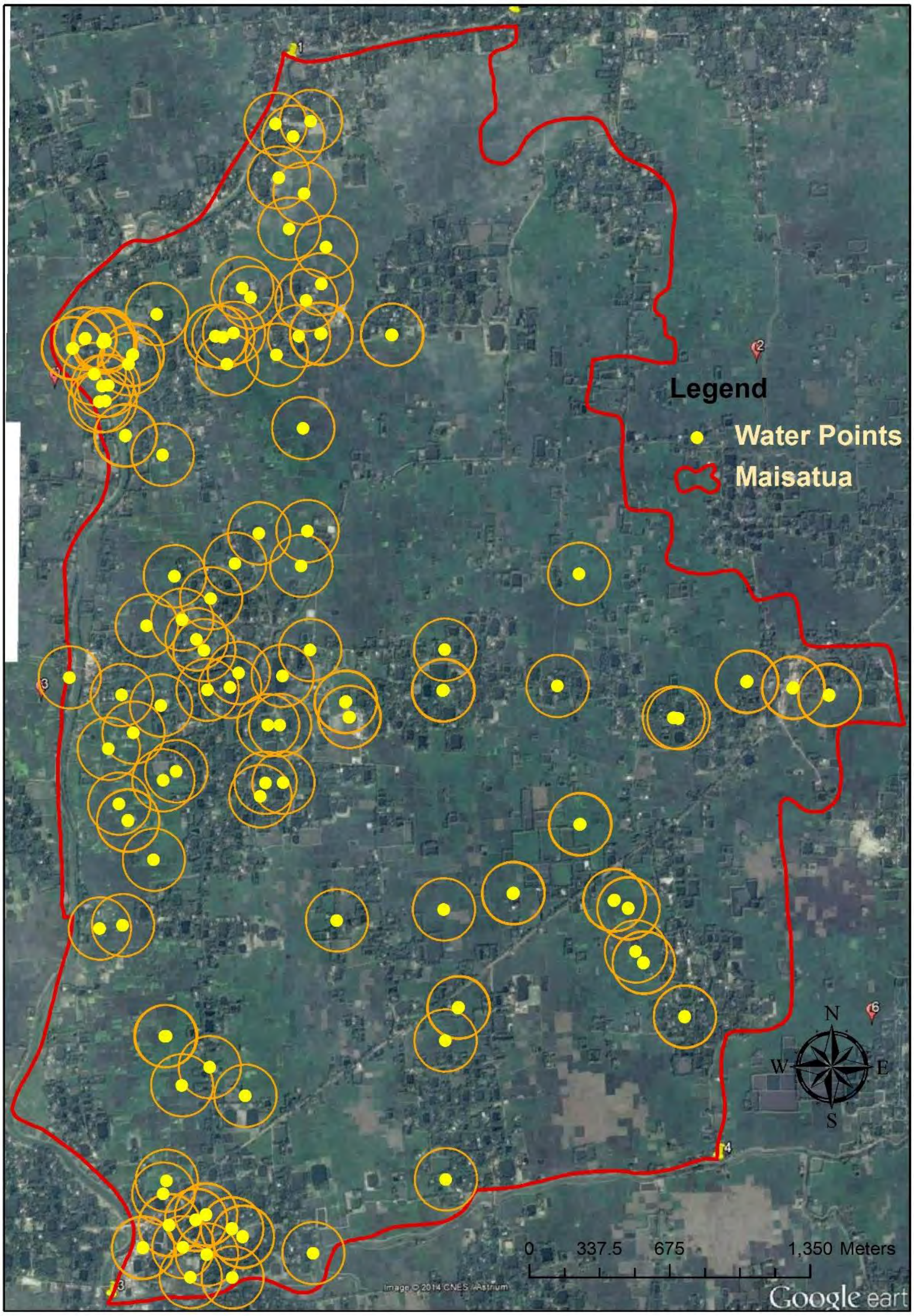
Water Supply Coverage In Khila Union



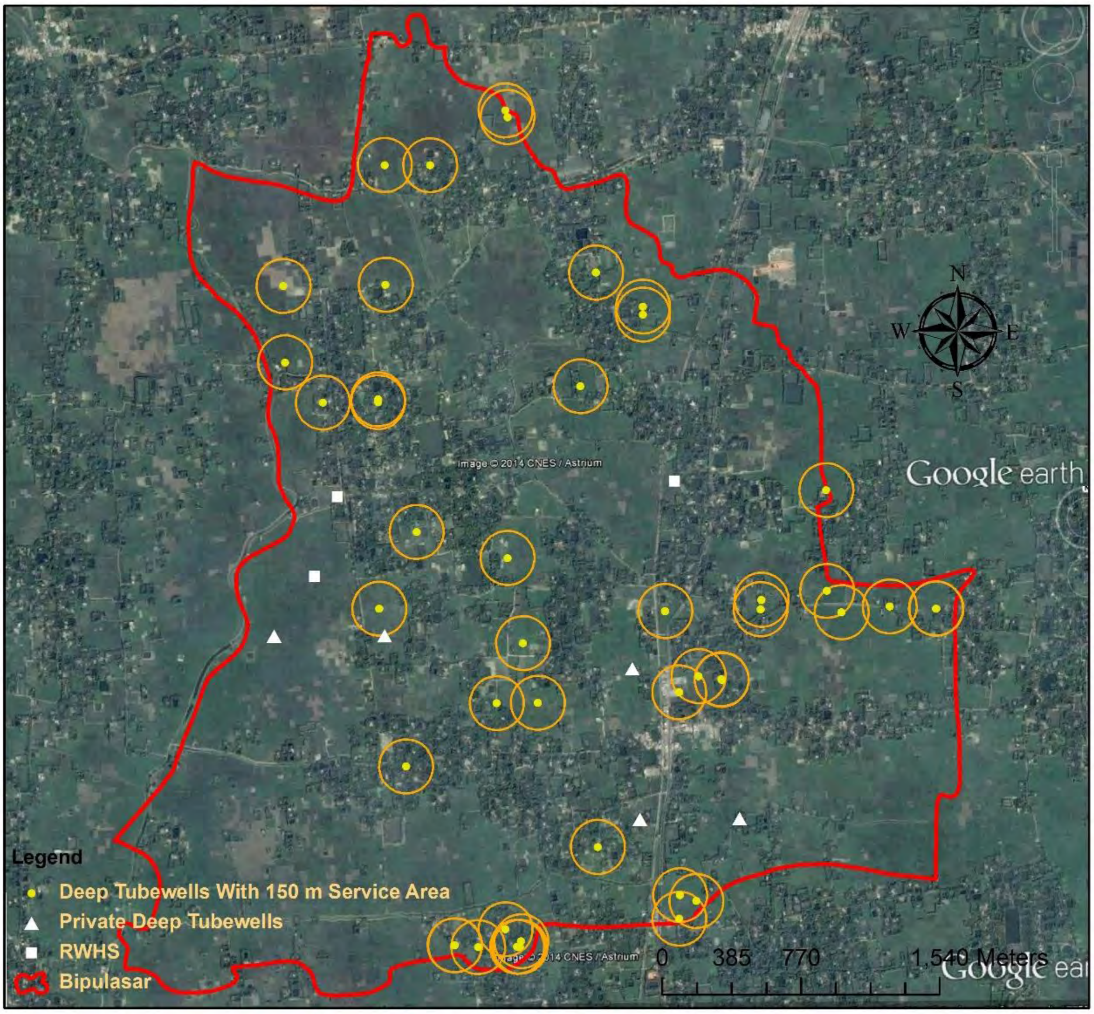
Water Supply Coverage In Hasnabad Union



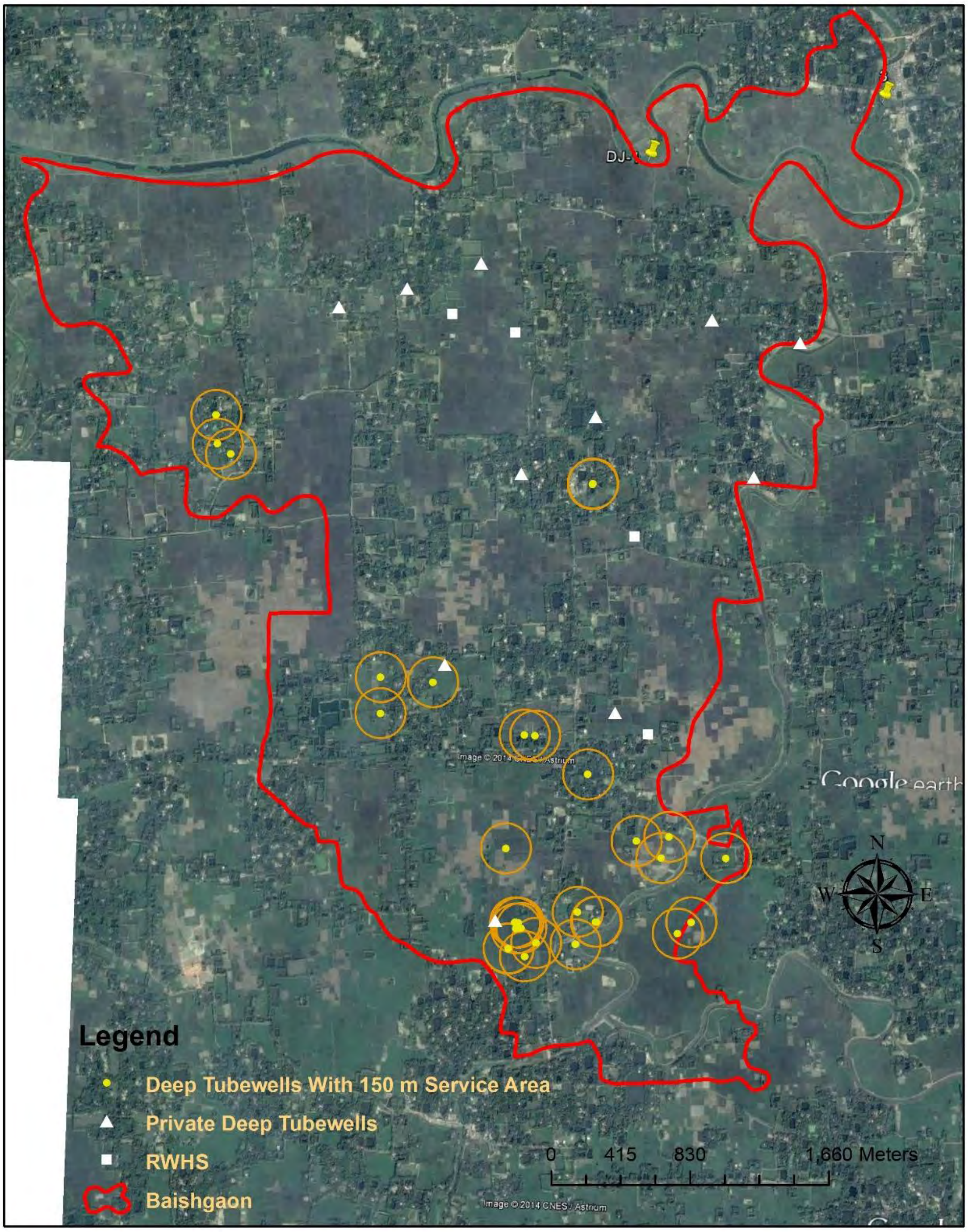
Water Supply Coverage in Maisatua Union



Water Supply Coverage In Bipulsar Union



Water Supply Coverage In Baishgaon Union



Water Supply Coverage In Lakshmanpur Union