PERCEPTION OF ARSENIC HAZARD AND FACTORS AFFECTING PEOPLE'S PARTICIPATION OF ITS MITIGATION IN THREE VILLAGES OF BANGLADESH

THESIS

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Muhammad Tauhidur Rahman, B.A.

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I would like to dedicate this thesis to my grandfather (passed away few months ago) who would keep me updated everyday with the newspaper headlines dealing with arsenic contamination during my field work in Bangladesh.

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CHAPTER I

INTRODUCTION

Despite being a country with one of the highest annual precipitation rates in the world, Bangladesh suffers from major shortages of pure drinking water. Over 85% of the nation's 133 million people live in rural areas and rely on hand-pump tube wells for drinking water supply (Bridge and Hussain 1999). Unfortunately, a large percentage of tube wells in the country are contaminated with naturally occurring arsenic, which has affected an estimated 35-75 million people to such an extent that scientists and policy makers consider it as the largest mass poisoning in human history (Smith, Lingas, and Rahman 2000).

The incidence of arsenic poisoning is now well documented. Increasing number of people complains suffering from arsenicosis and both government and non-government organizations (NGOs) are continuously struggling to combat the hazard and to create public awareness of the problem. Most people in Bangladesh are knowledgeable about arsenic contamination of tube-well water, and perceive arsenic poisoning as health hazard. There are numerous arsenic mitigation options available in the country. Some methods are more expensive than the others; some are free of charge while others are community-based options that need voluntary individual participation. Some rural persons are willing to pay the costs whereas others are more inclined to volunteer physically and not ready to get involved in monetary expense in the mitigation process. Still others are less informed, less knowledgeable and suffer from indecision about what to do (Rahman 2002). Since the arsenic mitigation effort is very important in saving millions of lives, and the processes require both monetary contribution as well as voluntary participation of individuals, people's awareness and perception of the problem may play an important role in their participation in the mitigation processes.

Studies dealing with arsenic contamination of drinking water in Bangladesh focused on four issues: causes of arsenic enrichment of groundwater and method of its release in drinking water, health impacts of arsenic poisoning, appropriate mitigation technologies, and people's awareness and attitude toward the problem. The first three issues received considerable attention from geologists, geochemists, and health scientists; while the fourth issue concerns social scientists and very little research has been done in this vein. To date, only two studies examined people's awareness of arsenic hazard and explored the role of location and evidence of symptoms of arsenic poisoning, gender, and age on the level of individual perception (Paul 2004; Khatun 2000). Numerous human ecological, socio-economic and political factors influence individuals' perception of the hazard; and clear perception influence decision-making process toward participation in its mitigation programs. Existing studies have not explored the role of various psycho-socio-economic-political factors in developing people's awareness and perception of arsenic hazard; and the implications of public awareness in long-term solutions of the problem are not fully understood. The present study purports to fill this gap in the literature by examining the psycho-socio-economic-political issues of people's awareness and perception of arsenic hazard and its mitigation in Bangladesh through micro-level household data analysis. Using three village's data collected from selected households, the study will examine people's perception of arsenic hazard, human ecological, socio-economic-political factors affecting the level of perception, and the role perception level on individual participation in community based arsenic mitigation activities.

The study is organized into six chapters. Chapter one explores the history and issues of arsenic research in Bangladesh, describes geomorphic units and aquifer characteristics, examines the nature and approaches of natural hazard research to outline the conceptual framework, objectives and significance of this study. Chapter two briefly describes the villages under study, their aquifer characteristics, and levels of arsenic contaminations and its hazardous risks. Chapter three provides a detailed description of data collection methods and analytical procedures undertaken in this the study. Chapter four presents the key findings of the study on the level of awareness and perception of arsenic hazard among the respondents, and its relationship with their human ecological and socio-economic-political conditions. Findings on respondent participation in arsenic mitigation activities and various factors affecting their participation decision are discussed in chapter five. Finally, chapter six summarizes the study and makes concluding remarks focusing on the hypotheses regarding arsenic hazard and its mitigation issues and discuses their policy implications, and provides directions for future research.

Historical Background of Arsenic Research in Bangladesh

Tube wells have been used in Bangladesh since the 1940s. Prior to that, the rural populace of the erstwhile Bengal province of British India relied on surface water collected from village ponds, while the urban population used the limited number of hand-pump tube wells and treated water supplied by the district and sub-divisional municipalities (Bengal Gazetteer 1940). After the independence of Pakistan in 1947, the Provincial Government of East Pakistan (now Bangladesh) emphasized the improvement of drinking water condition in rural areas, and provided tube-wells in most villages in the province. Over the past 32 years of independence of Bangladesh as a country, most rural households gained access to tube-well water that is regarded as the principal source of drinking water supply. Tube wells became very popular and safe because of the fact that the surface water sources in Bangladesh have been contaminated with microorganisms that caused various acute gastrointestinal diseases such as cholera in the rural areas. While very large proportion of rural population drink tube well water, its contamination with arsenic caused the worst public health hazard in recent history.

Arsenic poisoning in rural Bangladesh was first discovered in 1992, when faculty members from the School of Environmental Studies (SOES) in Jadavpur University of India noticed something unusual while working on groundwater contamination in Gobindapur Village of West Bengal (Chakraborti, Das, Samantha, Mandal, Chowdhury, Chanda, Chowdhury, and Basu 1996). In one family, none of the members were showing arsenical skin lesions except for a woman who came to West Bengal from Bangladesh after her marriage. On being interviewed, the woman said that many of her relatives in Bangladesh have similar skin lesions. She also reported that she had seen similar skin lesions among several other women and children in two neighboring villages. The SOES, in its report on West Bengal's arsenic calamity, thus stated that Bangladesh in all probability was arsenic-affected (Chakraborti, Das, Samatha, Mandal, Chowdhury, Chanda, Chowdhury, and Basu 1996).

Over the past decade since its detection, more information was gathered about the arsenic poisoning from those parts of Bangladesh that border the arsenic-affected areas of West Bengal. Laboratory analyses of hair, nails, and skin and urine samples of Bangladeshi patients found to be rich in arsenic. In early 1995, the Director of SOES informed the UNICEF of Bangladesh and World Health Organization (WHO) that Bangladesh was in all probability arsenic-contaminated. Since then, scientists, researchers, NGO, and government workers and health specialists have done significant research on arsenic contamination of drinking water and its health hazards.

Geomorphology, Aquifer Characteristics & Their Arsenic Enrichments

Bangladesh occupies most of the Bengal Basin where the Ganges, Brahmaputra, and Meghna Rivers confluence, and deposit some 2 billion tons of sediments annually derived from the surrounding Himalayan and Indo-Burman mountain ranges (Brammer 1996). The Bengal Basin thus contains some 16 km. thick Cenozoic sediments deposited sequentially during the Tertiary and Quaternary periods. The Quaternary sediments are deposited during Pleistocene and Holocene epochs (Morgan and McIntire 1959; Brammer 1996). Based on sedimentary deposits, the country can be divided into three broad geomorphologic units: the Tertiary Hills in the east and southeast, the Pleistocene alluvium terraces (Barind and Madhupur Tracts) in the central and northwestern parts, and the Holocene alluvium plains in rest of the country (Figure 1). The Holocene alluvium plain is further subdivided into Piedmont plain, Ganges-Brahmaputra-Meghna River floodplain, Ganges active delta plain in Sylhet basin, and coastal plain. Most aquifers in the country are found in the Holocene alluvium where the groundwater can be found at very shallow (10 meters) sediment layers. The tertiary hills provide minor aquifers. Aquifers in the deltaic and floodplains of the Ganges-Brahmaputra River systems are moderately to severely enriched in arsenic; the shallow aquifers in the Meghna

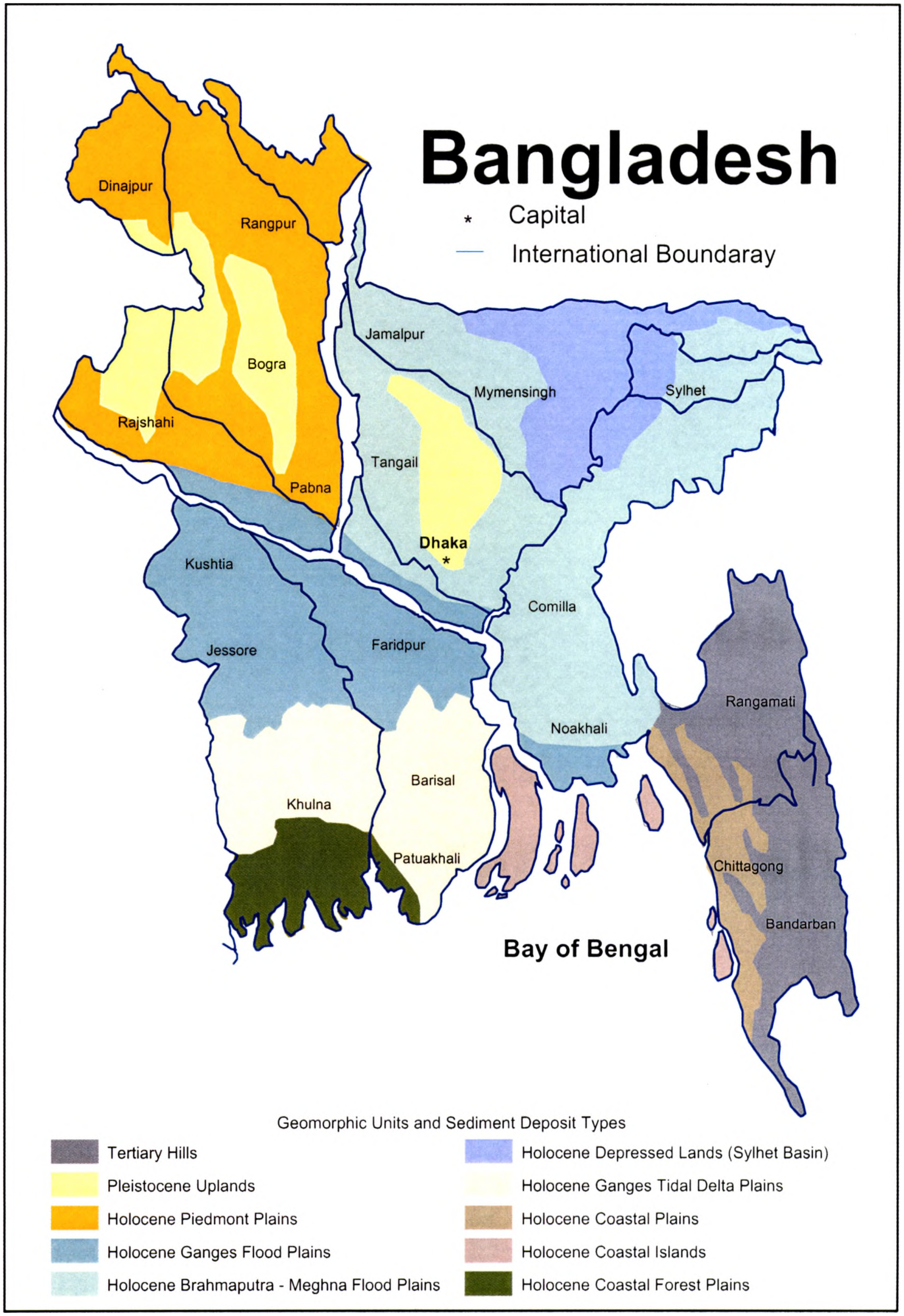

Figure 1: Geomorphic units & sediment deposit types of Bangladesh.

River floodplains, Sylhet basin, and coastal plains are extremely enriched in arsenic; and those in the Tertiary Hills and Pleistocene upland terraces are low in arsenic enrichment (British Geological Society 1998; Ahmed et al. 2004; Table 1; Figure 2).

Based on the studies conducted by the British Geological Society (BGS) and the Department of Public Health and Engineering (DPHE) of the Government of Bangladesh, aquifers in Chandpur, Comilla, and Noakhali in the Meghna estuary floodplain, as well as Munshiganj, Faridpur, Gopalganj, Shariatpur and Satkhira districts in the Ganges River floodplain and Deltaic plains are extremely rich in arsenic (Figure 2). Elsewhere in the country, somewhat low to moderate enrichment of arsenic has been reported. Highest concentrations of arsenic occur between 20 m and 50 m in the zone of composite aquifer. The sediments at shallower depths (<20 m) and greater depths (>150 m) are generally arsenic free.

The sediments in the Bengal Basin can be grouped into 4 textural classes: clay, silty clay, silty sand and sand. From the surface down, the upper aquifer contains silt and clay, the composite aquifer contains very fine to fine sand, main aquifer contains medium to coarse sand; and low aquifer contains deep clays and silt. Drinking water tube wells drill water from the composite aquifers, whereas the irrigation wells tap water from the main aquifers. Petrographic analysis reveals that the arsenic rich aquifer sands are quartzolithic and derived from

Geomorphic Units	Geographic Location	Aquifer Characteristics & Level of Arsenic Content in Sediments
Tertiary Hills	Eastern and southeastern regions	Due to mountain terrain, non-uniform Dupi Tila and Tipam sand aquifers are arsenic free.
Pleistocene Uplands	Barind and Madhupur Tracts of central and northwestern regions	Dupi Tila aquifer buried under 10m-100m Pleistocene clay. Confined to leaky confined aquifer is composed of fine to medium grain sand which is low in arsenic enrichment.
Piedmont Plain	Northwestern regions	Unconfined very shallow aquifer composed of medium to coarse grain sand low in arsenic enrichment.
Holocene Floodplains of the Ganges, and Brahmaputra-Meghna River Systems	Central, eastern, and southwestern regions	Unconfined very shallow aquifer is composed of fine to medium coarse sand moderately to severely enriched in arsenic.
Active Tidal Delta Plain	Southern regions	Unconfined very shallow aquifer is composed of fine to medium coarse sand moderately to severely enriched in arsenic.
Depressed land of Sylhet Basin	Northeastern regions	Large natural depression locally called haors and bills. Confined to leaky confined aquifer is composed of very fine sand moderately enriched in arsenic.
Coastal Plains, forests, and islands	Southern regions	Unconfined shallow upper aquifer is composed of saline, very fine sand severely enriched in arsenic. Confined lower aquifer is composed of arsenic free fine to medium grain sand.

Table 1: Geomorphic units of Bangladesh, their locations and aquifer characteristics.

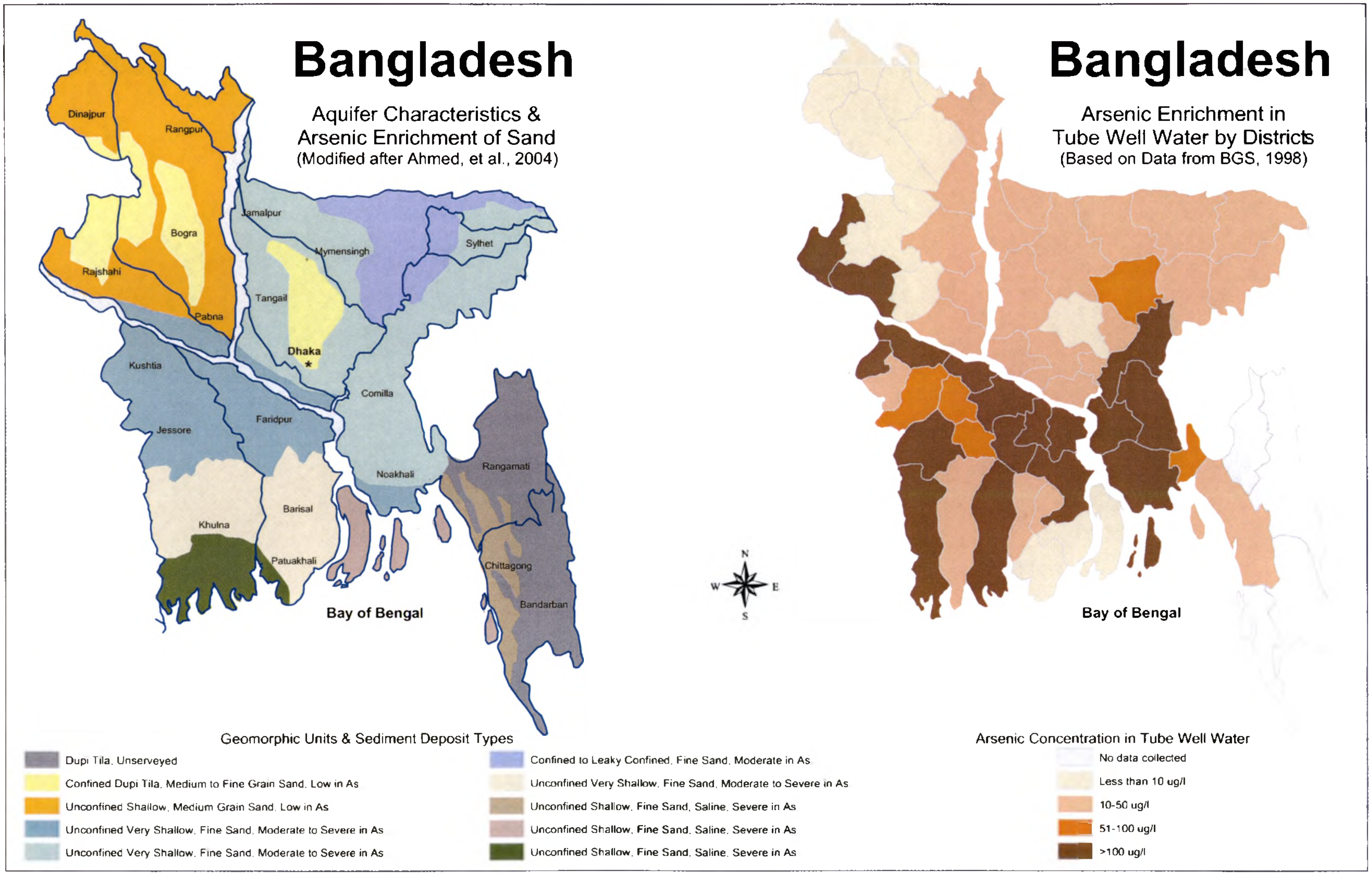

Figure 2: Aquifer characteristics and level of arsenic concentration in sediments and tube wells of Bangladesh.

orgogenic sources (Ahmed et al. 2004). Analyses (HNO_3 extraction) of sediment samples collected from alluvium aquifers located in different parts of the country revealed that the aquifer sediments rich in $FeNO_3$, $MnNO_3$, $AlNO_3$, and PNO_3 are also rich in $AsNO_3$ and they are strongly positively correlated; that AsOX (arsenic oxalate) is positively correlated with FeOX, MnOX, AlOX; that finer sediments rich in sulfide minerals also contain high percentage of arsenic; and that reductive dissolution of iron oxyhydroxide present as coating on sand grains is the main mechanism to release arsenic into ground water in the sandy aquifer sediments (Ahmed et al. 2004).

Sources of Arsenic Poisoning

To date, arsenic research in Bangladesh has identified several sources of arsenic release into the groundwater. In 1996, Chakraborti and his research team conducted a geo-chemical survey in the six districts of West Bengal, India, bordering western districts of Bangladesh. They analyzed the subsurface sediment samples and found the trace of arseno-pyrite or ferrous hydroxide minerals that release arsenic into ground water upon oxidation (Bridge and Hussain 1999). The process of oxidation of pyrites is fostered by withdrawal of large volume of ground water for irrigation. Large scale irrigation lowers the ground water table to such an extent that the sediments containing arseno-pyrites becomes exposed to oxygen (Bridge and Hussain 1999). This explanation is known as the oxidation hypothesis.

Nickson and colleagues suggested the 'reduction hypothesis' which contends that arsenic is released to ground water through reduction of arseniferous oxyhydroxides under anoxic conditions developed during sediment burial (Nickson, McArthur, Ravenscroft, Burgess, and Ahmed 2000). The reduction process is driven by the microbial oxidation of organic carbon in aquifer sediments.

The third potential source of arsenic is the coal mines of the Rajmahal-Chotonagpur basin and its overlaying basaltic rocks in West Bengal. The isolated outcrops of sulfide contain up to 0.8% of arsenic in the Darjeeling and the Gondwana coal belt, which is drained by the Damodar River. Weathering of arsenic-rich minerals releases finely divided iron oxyhydroxides, which would strongly absorb co-weathered arsenic (Thornton 1996). This process would have supplied iron oxy-hydroxide containing arsenic to sediments carried and deposited by the Ganges River.

Another hypothesis, called agro-chemical hypothesis, contends that indiscriminate use of arsenic containing chemical fertilizers to increase food production may have released arsenic to ground water. Dams and barrages such as Farakka, Tista, and twenty-eight others in India and Bangladesh are also being blamed since they allowed over uses of groundwater and diversion of surface water from the rivers. Finally, rural electrification via installation of millions of electric poles coated with paint containing arsenic and lead may also be responsible for releasing arsenic into the groundwater (British Geological Society 1998).

Most scientists and researchers consider decomposition, oxidation and reduction of pyrite minerals as major causes of arsenic release in groundwater. Hypotheses such as uses of agro-chemical fertilizers and diversion of the Ganges River water are particularly weak because of the facts that the entire country is not affected by Farakka or other dams; only the southwestern districts located adjacent to the Ganges River are affected, but arsenic contamination is not restricted to these districts. Also, import of fertilizers containing arsenic stopped several years ago but that did not stop its contamination. All these hypotheses suggest that arsenic mobilization in ground water is a complex natural geochemical process and more than one source is responsible for it.

Health Hazards Associated with Arsenic Contamination

Arsenic is a mobile element in the environment and may circulate in various forms through the atmosphere, water, and soil before finally entering into the bottom sediments and the sea. Humans can be exposed to it in many different ways: by ingestion of contaminated water and food; by ingestion of arsenic contaminated medicinal preparations; by homicidal and suicidal ingestion of arsenic compounds; and by inhalation of dust containing arsenic or volatile arsenic compounds or through prolonged usage of arsenic containing preparations (Luh, Baker, and Henley 1973).

Health experts believe that within 24 hours after ingestion, arsenic concentrates in liver, kidneys, lungs, spleen, bones, muscles, and skin tissues; and a small amount reaches the brain, heart, and uterine tissues. Urination is the only pathway for arsenic removal from human body; and laboratory analysis of urine sample is the common method to detect arsenic poisoning (Le and Ma 1998).

The health effects of arsenic ingestion through drinking contaminated water appear slowly, and skin pigmentation emerges as the first symptom (Smith, Lingas, and Rahman 2000). The most widely noted effects of chronic arsenic consumption are skin lesion, skin pigmentation (dark and white spots on skin), keratoses, and skin cancer (National Research Council 1999). The times from exposure to manifestation varies between 5-10 years, and very prolong exposure for 10-20 years can also cause lung, bladder, kidney, and liver cancers (Bridge and Hussain 1999; Smith, Lingas, and Rahman 2000). Arsenic ingestion causes diabetes mellitus, cardiovascular diseases, hypertension, and interferes DNA replication, DNA repair and cell division (Karim 2000; Rahman, Tandel, Chowdhury, and Axelson 1999).

Mitigation Options

Immediate cure for diseases associated with arsenic poisoning is limited to dietary supplements of vitamins and minerals such as Sodium Arsenite and Sodium Selenite, and drinking of plenty of arsenic free water to flush out the element from the human body. One of the primary solutions to prevent arsenic hazard is, therefore, to ensure adequate supply of arsenic-free water to the people living in the affected areas (Paul and De 2000). In Bangladesh, varieties of techniques are available to remove arsenic from drinking water. They include conventional co-precipitation with ferric chloride, lime softening, filtration using exchange resins and activated alumina as absorbents, and membrane filtration processes (Sorg and Logsdon 1978; Hering, Chen, Wilkie, Elimelech, and Liang 1996; Meng, Korfiatis, Christodoulatos, and Bang 2001). Sand filter system (PSF) is also used to purify surface water collected from ponds and rivers (Yokota, Tanabe, Sezaki, Akiyoshi, Miyata, Kawahar, Tsushima, Hironaka, Takafuji, Rahman, Ahmad, Sayed, and Faruquee 2001). In northwestern districts, arsenic free rainwater is collected and reserved for cooking and drinking purposes (Paul and De 2000).

New techniques facilitating faster removal of arsenic from drinking water at lower costs are also under experiment in Bangladesh. In a recent conference held at the University of Rajshahi in Bangladesh, researchers from the Indian subcontinent proposed several new arsenic removal techniques. They include a combination of biomass treatment, froth-flotation, and minimum-suspended fluidized bed reactors. Uses of several flocculent chemicals composed of iron oxide, alum, activated charcoal and calcium carbonate mixed in definite proportions, homogenized and micronized are also tested to explore if they are capable of absorbing soluble arsenic from ground water (Ahmed et al. 1999, p.49).

Various NGO's and health organizations provide funding for arsenic research and health care extension services. In 1998, Bangladesh received about $44 million from the World Bank, the United Nations Developmental Program, and Swiss Government as interest free loan to establish a 10 year long-term mitigation program that could cost over $200 million (Lepkowski 1998). Several US agencies, for example, the Sandia National Laboratories, and the Trade Development Agency (TDA), provided $1.17 million grant to perform mineral surface analyses of arsenic-contaminated shallow aquifer materials and to develop a treatment system that is both technically and socially acceptable to the people of Bangladesh (Lepkowski 1998). The goal is to unravel the geo-chemical controls on arsenic mobilization that is affecting the drinking water supply for a very large proportion of the national population.

The National Science Foundation provided two separate grants in August, 2000 to Massachusetts Institute of Technology, and the University of Cincinnati, to explore the cause of high arsenic enrichment in ground water in Bangladesh, and to examine how and to what degree a deep well drilling can avoid the contamination of arsenic. The foundation also granted $44,000 fund to Columbia University to characterize the subsidence and stratigraphy of the Ganges-Brahmaputra delta and the geologic processes that have shaped them, including the mobilization of naturally occurring arsenic from the underlying sediments (Weekly Bangladesh 2001).

In summary, the contamination of drinking water in Bangladesh has received wide attention from the natural, biological and social scientists over the past decade. They have proposed several hypotheses relating the contamination of arsenic to natural and human-induced factors. They have also identified the health effects of arsenic poisoning that includes cancer and death. In order to stop this mass poisoning, different mitigation options are tested and researched to find one that is simple, effective, and will be accepted by the rural population.

Conceptual Framework

In the context of natural hazard studies, the term "perception" can be defined as an individual's judgment of the acceptability of a given natural hazardous situation (Short 1984). Since the 1960s, issues associated with human perception of natural hazards received wide attention from social and behavioral scientists including geographers. In geography, hazard perception research began in the early 1960s when Robert W. Kates, Ian Burton, and Gilbert F. White developed the human perception to natural hazards (flood, drought, earthquake, and cyclone) research at the Chicago School of Geography (White 1974; Kates 1971). The word "risk" refers to the probability of occurrence of a hazardous event; whereas the term "perception or perceived risk" is often used in the literature as an individual or group understanding of various naturally occurring risk situations which may be different or modified from what is scientifically measured or understood form of the risk, or "real risk" (Coleman 1993). Most studies dealing with risk perception revealed that human perception to natural hazard is affected by the psychological makeup of individuals, or by the degree to which the individual has access to, and correctly interprets technical information on the hazard risk (Linstone 1981). Several studies also recognized that organizational and social structural variables such as ethnicity, religion, age and sex, occupation, income, marital status, and organization membership also affect human risk perception (Watts 1983; Paul 1998; Haque and Zaman 1993; Armstrong 1995).

To date, researchers follow either human ecology or structural political economy approach to study natural hazards. The human ecological approach (emerged in the 1970s and 1980s) recognizes the importance of individual actions and decision-making in responding to natural hazards. Such individual actions are influenced by the psychological make up of the individual, which affects his/her perception to the risk (Kates 1971). Several empirical studies in social and behavioral sciences suggest that perception and human behavior are strongly related in a very complex manner and such relationships are modified by a wide range of human ecological factors (Cole and Whithey 1982). Factors mediating human perception and behavior may include:

1. Perceived cause of the hazard;
2. Degree to which the information about the hazard was available;

3. The media in which the information was presented;
4. Institutions evaluating the risk;
5. Individual's previous experience about the risk and potential damage;
6. Individual willingness to participate in group activities (toward mitigation);
7. Positive view about the potential group leaders;
8. Confidence in the validity of the social mitigation actions; and
9. Perceived benefits of mitigation actions;
10. Physical proximity to the hazardous area (Barton 1970; Burton and Kates 1964; Burton, Kates and White 1978; Coal and Withy 1982; Linstone 1981).

On the other hand, followers of the structural-political economy approach argue that perception of hazards and individual response to their mitigation process is related to socio-economic conditions and social-political linkage of the individuals involved (Watts 1983; Hewitt 1983; Blaikie 1994). Individual perception and response to natural hazards varies widely depending on social and political economic conditions such as literacy, land ownership, occupation, and individual income (Susman 1983; Blaikie 1994).

In a real world situation, an individual level of perception and human response to hazards are influenced not only by the human ecological factors (outlined earlier) but also by social and political economic conditions in which the individual operate (Linstone 1981; Paul 1998; 1995; Haque and Zaman 1993;

Tucker and Napier 1998). A single approach to study perception of arsenic hazard in Bangladesh, therefore, would be less useful than an integrated approach.

The issue of people's perception of arsenic hazard emerged as an important research topic in Bangladesh given the fact that arsenic contamination of drinking water has affected large portion of the nation's population in recent years. Understanding people's perception and factors affecting their perception level has an important policy implication in the sense that better perception improves individual participation level in the mitigation process. To date, research dealing with the determinants of people's perception toward arsenic poisoning and their participation in mitigation process are not adequate. In a recent study, Paul (2004) explored the level of awareness of arsenic hazard among 356 respondents, selected from low to medium risk region in north and eastern districts of Bangladesh. Following the social structural approach, he concluded that factors such as residence in the risk region, level of education, age and gender determine the individual level of awareness (Paul 2004). In another study, Khatun (2000) examined the awareness of arsenic poisoning among Bangladeshi villagers and found that direct observation of sufferings of arsenic patients influences individual awareness of the hazard (Khatun 2000). Khatun's work falls into the human ecology approach in the sense that individual's previous experience and mental image about the hazard influences his perception level (for example, see Cole and Whithey 1982).

In addition to the role played by limited numbers of demographic, social and ecological variables examined in existing studies, there are many other factors that affect individual perception level. For example, human ecological force such as government and NGO publicity via newspapers, radio and television media has improved the level of awareness among rural population in recent years. Often individual's income enhances ones accessibility to information media, community leadership and extension services and thus improves his perception level. Higher income provides the ability to purchase water purification and health care devices. Physical proximity to the hazardous area also affects individual perception (Burton, Kates, and White 1978). Existing studies have not examined the influence of these additional socio-economic and human ecological factors on human perception. Also what was not examined is to what extent the level of individual perception of hazard would influence his decision to participate in its mitigation process. Considering the importance of both human ecological and socio-economic-political factors in shaping the individual perception of natural hazard, and attitude toward its mitigation process, the present study is based upon the conceptual framework underlying that both the approaches are merged. It is assumed that a wide range of human ecological and social structural factors influences human perception of arsenic hazard in Bangladesh.

Objective of the Study

This study will examine the level of public awareness and perception of arsenic contamination of drinking water in Bangladesh. It will examine the influence of selected human ecological and socio-economic-institutional factors on the development of individual perception toward arsenic hazard among residents of three villages where a high degree of arsenic contamination of tube well water has been detected. The study will also examine the relationship between the level individual perception of the hazard and his level of participation in the arsenic mitigation process.

The study will be conducted in four stages. First, detailed field survey will be conducted in three selected villages where arsenic contamination is at high level of hazard risk. During this field survey, information about the village environment, aquifer conditions, source of drinking water, farming and demographic characteristics will be gathered. The field survey will also involve household questionnaire interviews seeking responses to various human ecological and socio-economic-institutional aspects of the household; the questionnaire will be structured to investigate the level of awareness and perception to arsenic hazard, and respondent's willingness to participate in the arsenic mitigation process. Second, based on individual responses to a range of questions related to perception of arsenic hazard in the study area, a perception index will be constructed for each respondent household. Third, the impacts of selected human ecological, socio-economic-institutional variables on the perception index will be examined using bi-variate and multivariate statistical methods. Finally, the impacts of human perception index and its underlying socio-economic and institutional components on the issue of individual decision-making behavior to participate in the mitigation action will be examined. The study will examine two working hypotheses:

Hypothesis 1

- Individual perception (expressed as an index) of arsenic hazard is related to household income, education, possession of information media, institutions presenting the information, presence of arsenic patients in the family and distance from where the drinking water is collected by the individual.

Hypothesis 2

- Individual willingness to participate in arsenic decontamination and mitigation actions is positively related to individual level of the perception (measured by index).

Significance of the Study

The study is expected to make significant contribution to our knowledge of arsenic hazard in two ways. First, this type research has not been undertaken before in the villages under study, and thus the data collected and used in this study will be extremely valuable and important for future research and planning arsenic mitigation projects. Second, earlier hazard research in Bangladesh examined the influence of either social-economic or limited human ecological factors on the development of perception of arsenic hazard. This study seeks to investigate the impact of both socio-economic-institutional as well as human ecological factors on human perception and decision making in hazard mitigation.

CHAPTER II

STUDY AREA

The present study was conducted in three villages, namely, Rajarampur in Chapai Nawabganj, and Samta and Bakaborshi in Jessore districts in western and southwestern part of Bangladesh (Figures 4, 5, and 6). The villages were selected on the bases of two criteria: quality of tube well water, and presence of patients suffering from arsenicosis. Earlier water quality tests conducted by the British Geological Survey (BGS) identified both Chapai Nawabganj and Jessore districts as high risk regions where majority of tube wells' water is severely contaminated with very high concentration of arsenic (>0.30 mg/l), and large number of people have been suffering from arsenic poisoning. The three villages selected for this study, in particular, have drawn considerable interest from scientist and researcher from around the world because their high risk of arsenic hazard, a reason that justifies their selection for this study.

The three villages are located in the Ganges River floodplains where they experience the tropical monsoon climate with prolonged dry season with excessively high summer temperature (>43°C) and evapo-transpiration. They receive an annual rainfall of 1,448-1,600 mm, 82% of which occurs during the monsoon months (June-October), 14% during the Nor'wester months (March-May), and 4% in post-monsoon and winter months (November-February). Pre-monsoon drought affects the village hydrology. Seasonal rainfall supports three distinct cropping seasons: the *kharif* (March-May), the *haimantic* (June-October), and *rabi* (November–February). Aman, aus and boro rice (Oriza sativa L. var.) and wheat are the principal food crops grown in all three villages.

During the preliminary reconnaissance survey and group discussions, residents of all three villages reported that they rely on tube-well water for drinking and cooking and use surface water from pond and river for washing and bathing. The villages differ in terms of aquifer characteristics, socio-economic conditions of people, arsenic concentration in the tube well water, and risk of arsenic hazard as indicated by the number of tube wells contaminated, and the number of arsenic victims per 1,000 people (Table 2 and Figure 3). Several key demographic and socio-economic characteristics of the villages are briefly discussed here.

Rajarampur

The village Rajarampur is the northernmost village under study (Figure 4). It is located within the Chapai Nawabganj Municipal area at about 4 km west of the municipality office. The village was established in 19th century at the time when Nawab Siraj-ud-Daula set-up revenue collection offices in Chapai

Village and District	Aquifer Type and Arsenic Enrichment	Percent of Tube Wells Infected	Arsenic Amount Present	Number of Patients/1000 People	Risk Level
Rajarampur Nawabganj	Unconfined to leaky confined aquifer composed of 4.2 – 4 7 mg/kg of arsenic	59%	1.5 mg/l	37	High
Samta Jessore	Unconfined very shallow aquifer composed of 5.3 mg/kg of arsenic	91%	1.37 mg/l	95	High
Bakaborshi Jessore	Confined to leaky confined 5.6 mg/kg of arsenic	65%	0.40 mg/l	50	Moderate -high

Table 2: Assessment of village level risk of arsenic hazard of the villages under study in 2003.

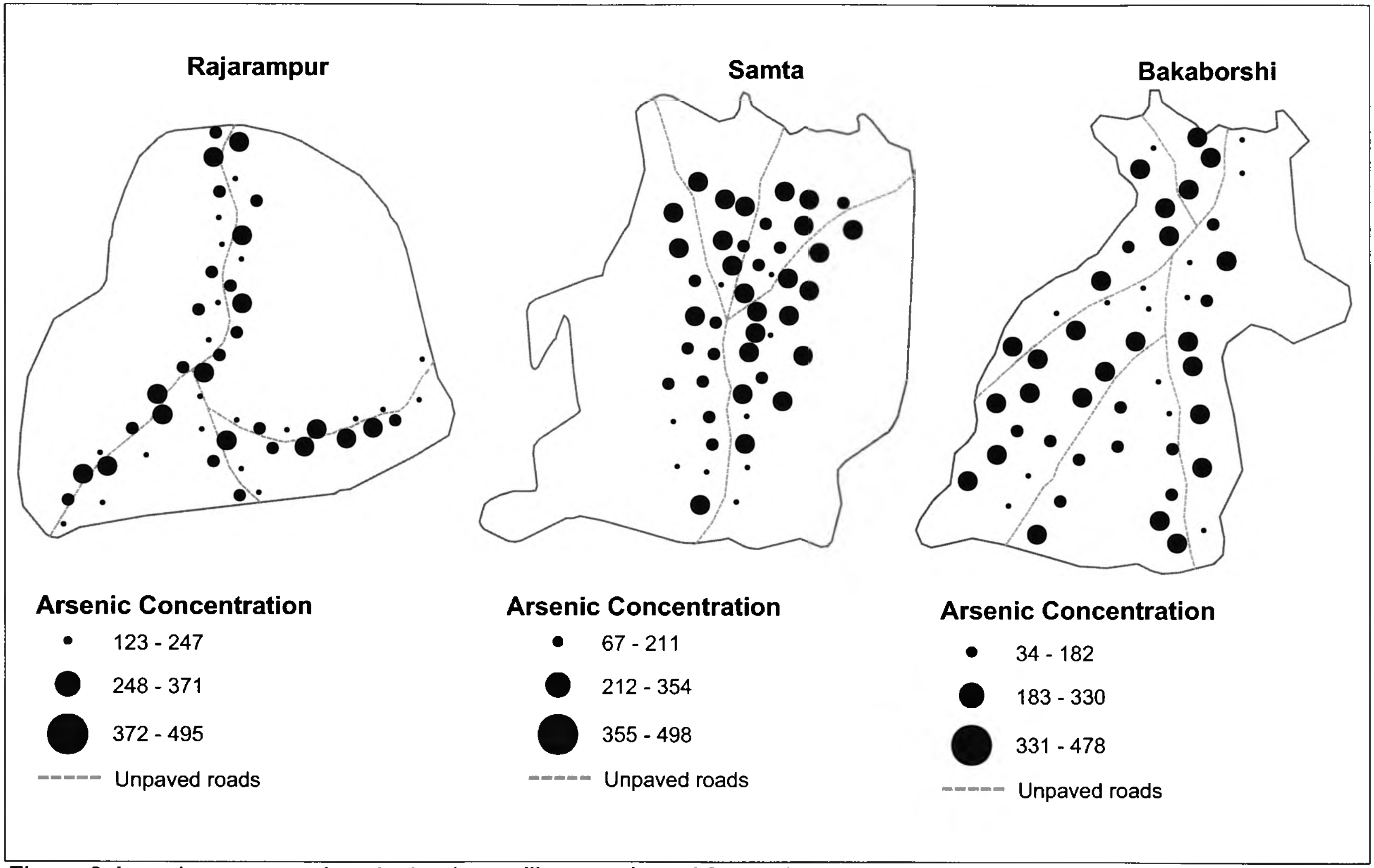

Figure 3:Arsenic concentrations in the three villages selected for study.

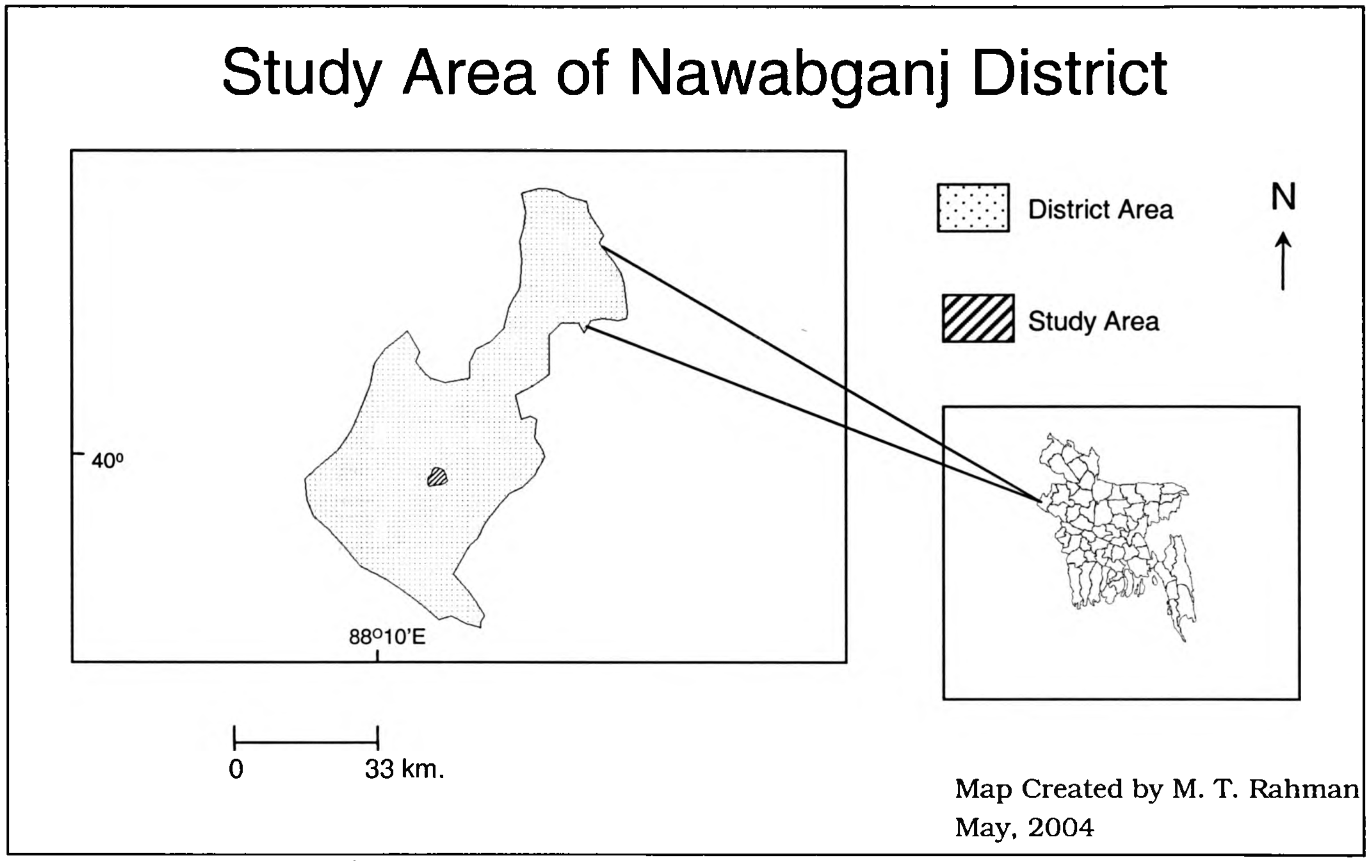

Figure 4: The location of Rajarampur in Nawabganj district.

Nawabganj town (District Gazetteer of Rajshahi 1973). The village has an area of 1,600 ha with a total population of 12,298 living in 2,030 family households. Despite its location in an urban municipal area, majority of the village residents are farmers; only 23% have formal education, which is typical of the western peripheral districts of Bangladesh.

The village aquifer is unconfined to leaky confined type that contains very fine sand moderately to severely enriched in 4.20-4.70 mg/kg of arsenic. Groundwater occurs within 10 m from the surface. Over 92% of the village's 410 tube wells tap water from 30-50 m deep aquifer; the tapped water contains 1.955 mg/l of arsenic (Ahmed et al. 2004; British Geological Society 1998).

Because of its location within the urban municipal area, the village is served by tap water, electricity, and sanitary facilities. However, about 70% of the village population uses tube well water for drinking purposes because not every family can afford to pay the high cost of the tap water supply. Large numbers of the village residents (37 persons per 1,000 people) are suffering from arsenic poisoning. The village poses a high risk of arsenic hazard considering the severity of contamination of water and the number of arsenic patients. The latter incidence has drawn considerable interest from foreign researchers.

Samta

The village of Samta is a part of Sarsa Thana in Jessore district in the southwestern part of Bangladesh (Figure 5). It is located at about 42 km south of Jessore town on the west bank of the Betravati River, a distributary of the Ganges River. About 2.2 km^2 in area, the village is the oldest rural settlement in the area and has a total population of 6,500 living in 829 households. Over 70% of the village's population is engaged in farming; 29% literate who engaged in business and government/NGO salaried jobs. The village is linked to Jessore and Satkhira towns by a concrete road.

The unconfined upper part of the village aquifer contains very fine to fine sand enriched in 5.3 mg/kg of arsenic, and groundwater occurs within a 10 m from the surface. The lower aquifer contains arsenic free medium to coarse grain sand (Ahmed et al. 2004; British Geological Society 1998). Over 76%of the village's 245 tube wells tap water from 30-50 m deep aquifer, which is severely enriched in arsenic. Ninety-one percent of the tube wells are contaminated with arsenic concentrations greater than 1.37 mg/l (based on field survey data). Village residents use tube well water for drinking and cooking purposes. A large number of residents (95 persons per 1,000 people) are severely suffering from various diseases related to arsenic poisoning. Considering the severity of water contamination and the presence of large number of patients, the village is identified as high risk region for arsenic hazard.

Bakaborshi

The village of Bakaborshi is located in Keshabpur thana of Jessore

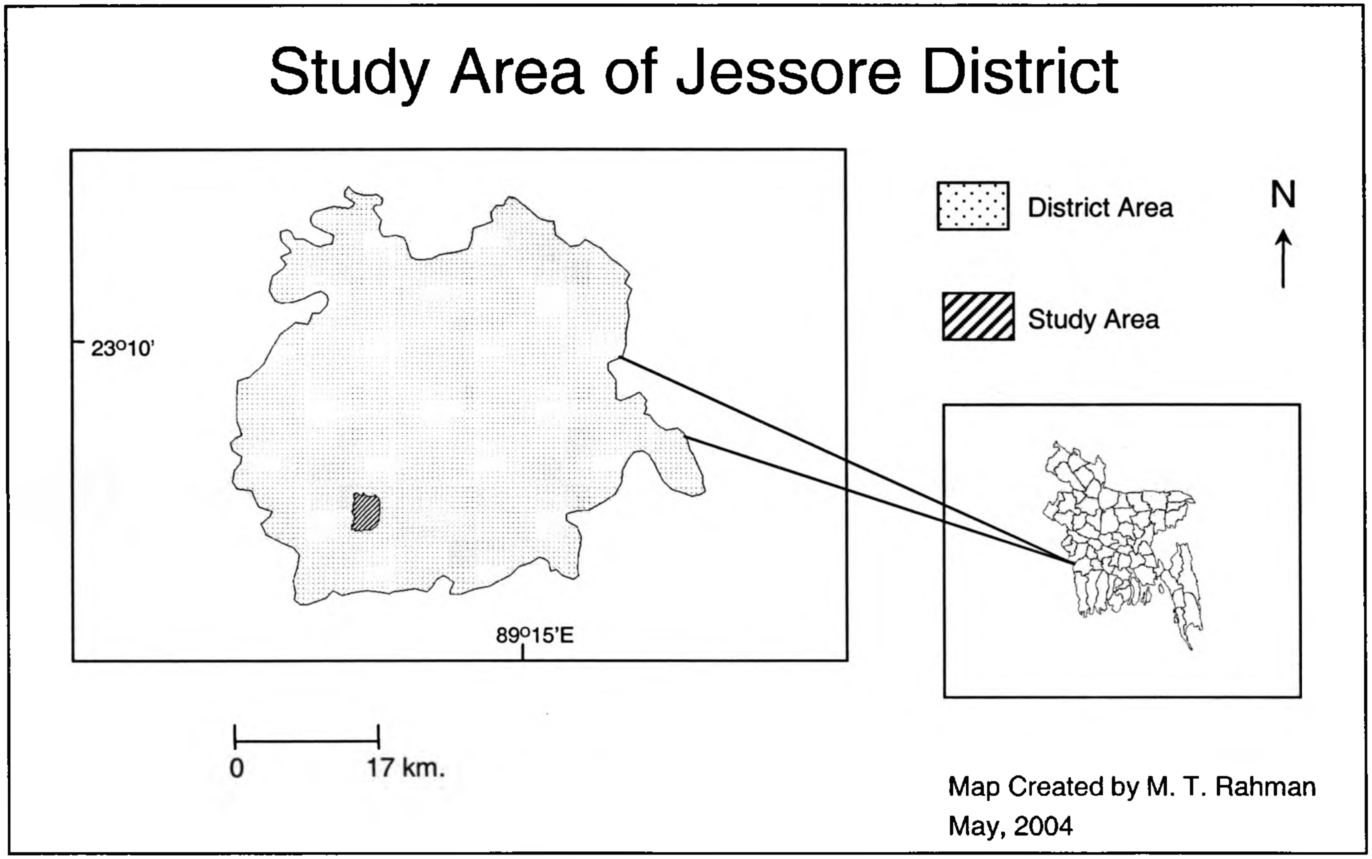

Figure 5: The location of Samta in Jessore district.

District (Figure 6). The village is linked with the Jessore-Satkhira highway by a concrete road. It has an area of 1,234 ha with a total population of 11,500 living in 1,295 households. Over 80% of the village population is small land holder farmers; the rest own small businesses or work as wage laborers.

The village aquifer is confined to leaky confined type and it contains fine sand moderately to severely enriched in 5.6 mg/kg of arsenic. The village land is regularly inundated by saline tidal water from the Kobadak River. Groundwater is saline and occurs within 10-15 m meters from the surface. The village residents tap drinking water from 50-70 m deep aquifers to avoid highly saline water.

There are 600 tube wells in the village of which 60% are contaminated with arsenic concentration of 0.40 mg/l. All villagers use tube well water for drinking and cooking, and 50 out of 1,000 people are suffering from arsenic poisoning. Among the three villages under study, arsenic concentration in tube well water is somewhat low in these villages; however, the presence of large number of asenicosis patients makes them moderate to high-risk villages.

The three villages selected for this study provide a unique field laboratory setting to explore the issues of human perception of a natural hazard and its mitigation process. The villages are located in different parts of the country, experience different socio-economic characteristics of their population, but all experience a very high risk of arsenic poisoning. Owing to their diversified socio-economic, institutional, and human ecological conditions, the village

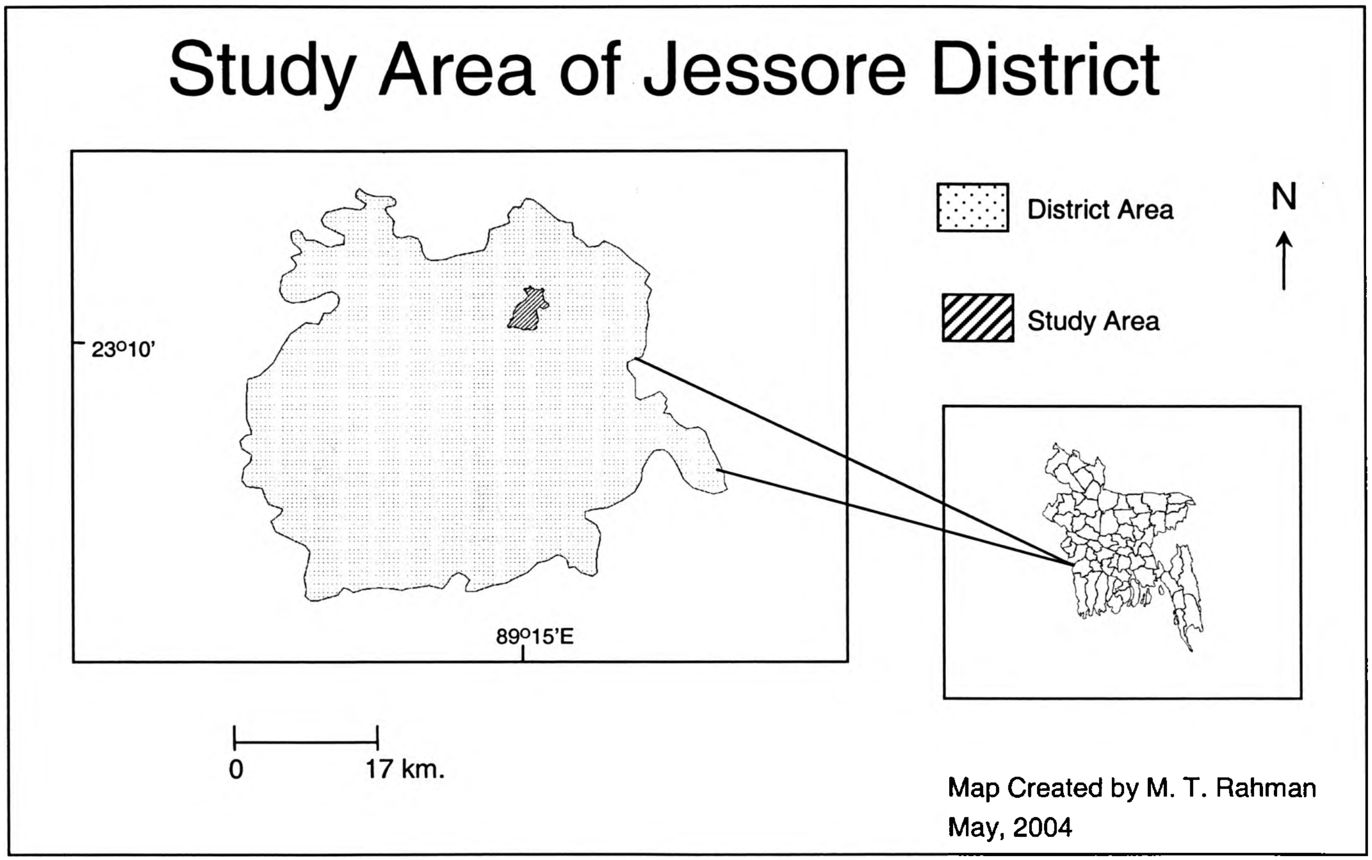

Figure 6: The location of Bakaborshi in Jessore district.

residents possessed different perception to this problem, and they have difference in opinions about its mitigation process. This study will attempt to explore some of these issues related to people's perception of arsenic hazard and their participation in its mitigation process.

CHAPTER III

DATA COLLECTION AND ANALYTICAL METHODS

The study aims to explore the level of awareness and perception of arsenic poisoning among a group of respondents selected from three villages in Bangladesh. It also aims to explore individual respondent's willingness to participate in arsenic mitigation process. The data for this study were collected through a detailed fieldwork conducted over a period of three months during the summer of 2003. Each village was visited twice: first, to conduct a reconnaissance survey to identify target respondents who would later be interviewed; and second, to interview the sample respondents using a detailed pre-tested questionnaire (Appendix 1). In each village, the large holder (>3 ha), medium holder (1-3 ha), and small holder (0.20-1 ha) households were identified during the reconnaissance survey. A sample of 50 households was randomly selected from each village except for Bakaborshi where 48 households were selected for the study. Thus a total of 148 households representing different farm size, occupation, literacy, and annual income categories were selected for personal interviews (Table 3 and Figures 7, 8, and 9).

Characteristics		Village			Total
		Rajarampur	Bakaborshi	Samta	
Village area in ha.		1,600	1,234	836	3670
Population in 2003		12,298	11,500	6,449	30,247
Landholding size	Small	18 (36%)	31 (62%)	19 (40%)	65 (44%)
	Medium	13 (26%)	11 (22%)	17 (35%)	44 (30%)
	Large	19 (40%)	8 (16%)	12 (25%)	39 (26%)
Occupation Level	Wage Labor	17 (34%)	28 (56%)	13 (27%)	59 (40%)
	Farmer	15 (30%)	14 (28%)	18 (38%)	46 (31%)
	Business	14 (28%)	3 (6%)	12 (25%)	28 (19%)
	Service	4 (8%)	5 (10%)	5 (10%)	15 (10%)
Years of Schooling	<5	15 (30%)	27 (54%)	11 (23%)	52 (35%)
	5-10	16 (32%)	14 (28%)	13 (27%)	43 (30%)
	>10	15 (30%)	5 (10%)	19 (40%)	38 (26%)
	Graduate College	4 (8%)	4 (8%)	5 (10%)	15 (10%)
Monthly Income (in Taka)	<2500	11 (48%)	20 (40%)	9 (19%)	45 (30%)
	2500-4999	26 (52%)	21 (42%)	21 (44%)	61 (41%)
	5000-9999	7 (14%)	5 (10%)	10 (21%)	21 (14%)
	>10,000	6 (12%)	4 (8%)	8 (17%)	21 (14%)

Table 3: Socio-economic characteristics of the respondents from the three villages under study.

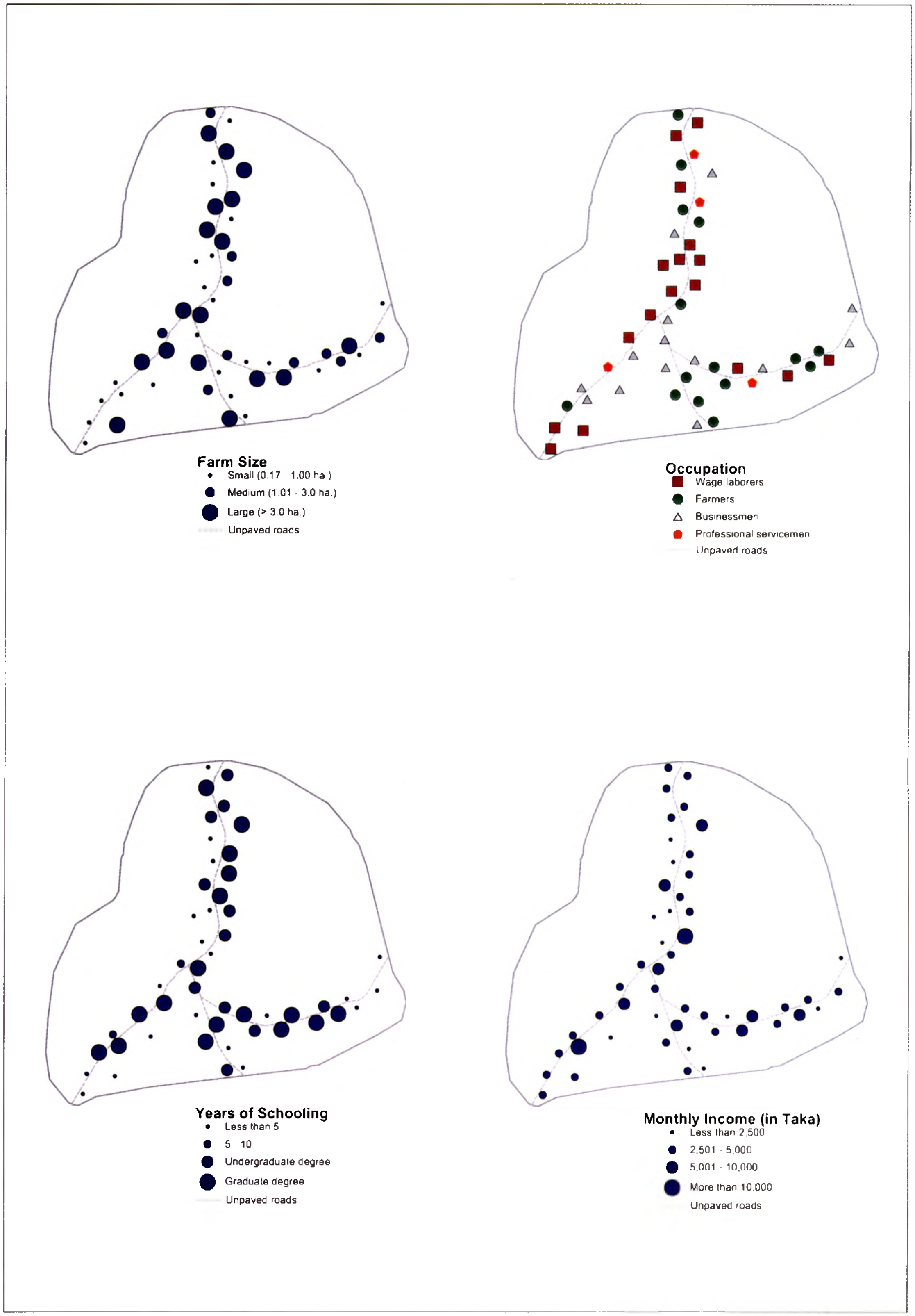

Figure 7: Socio-economic conditions of the respondents at the village Rajarampur in Nawabganj district.

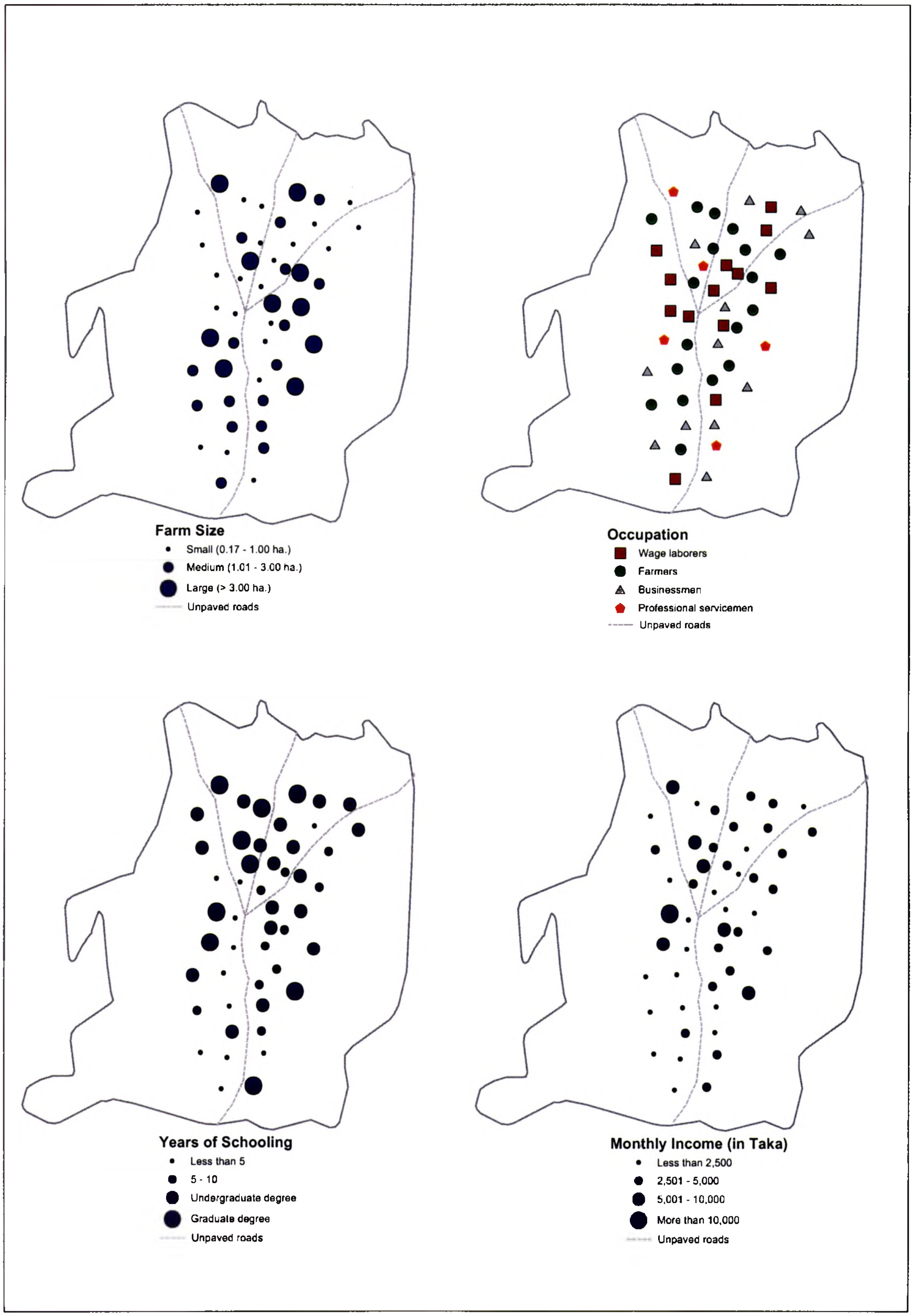

Figure 8: Socio-economic conditions of the respondents at the village Samta in Jessore district.

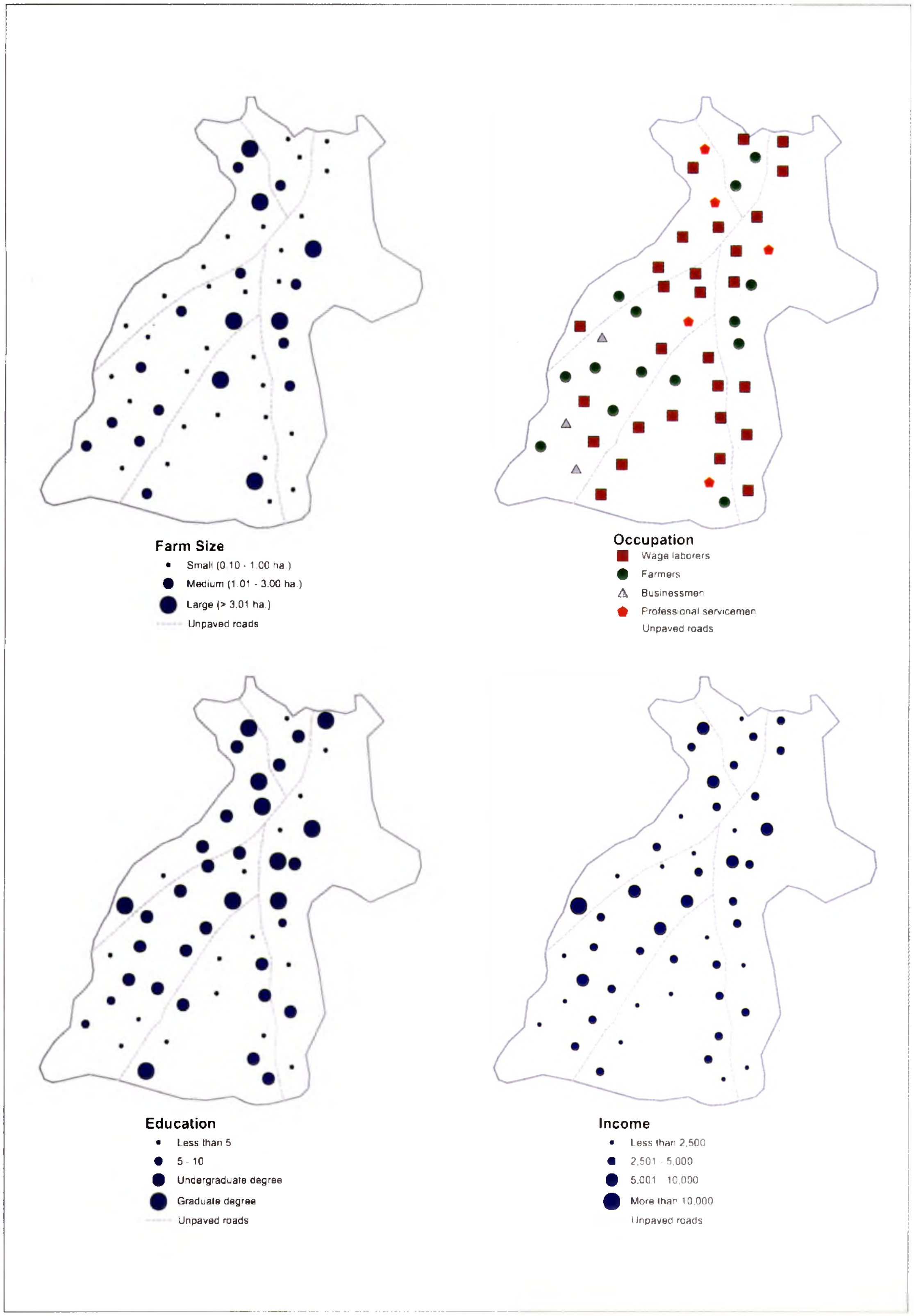

Figure 9: Socio-economic conditions of the respondents at the village Bakaborshi in Jessore district.

During the field research, four categories of data were collected through group discussion with the villagers and questionnaire interviews with head of households. First, during several group meetings, general information about each village, for example, its location, physiographic conditions, climate, population, literacy, occupation and economic activities, source of drinking water, and possible causes of arsenic poisoning of humans as perceived by the residents were collected. This information was used to describe the general characteristics of the villages and to understand why each village was vulnerable to arsenic hazard.

Second, during personal interviews with the heads of sampled households, data on family size, age and sex structure, farm size, level of education, occupation, annual income, political linkage, ownership of radio, television, and other mass media were collected. Third, also during the interview, respondents were asked to answer to a list of questions related to his knowledge and perception of arsenic contamination of drinking water, when and how such knowledge was acquired, what are the possible hazardous impacts of drinking arsenic contaminated water, and whether there was any arsenic patient in the family or not. Finally, the respondents were asked to provide information about their knowledge about arsenic mitigation options and expected costs involved. They were asked about their willingness to participate in both the community based and individual mitigation process.

In rural villages like these, usually the male head of household is interviewed; women members do not give interviews unless the issue directly concerns female health and there are female members in the research team. In this study, all the sample respondents were male head of households. Five local research assistants including one female student, who spoke Bengali language and its local dialects, asked all the questions in Bengali, since most of the villagers neither understood nor spoke English.

The most commonly used tool to study people's attitude and perception to natural hazard is the Likert scale, an attitude continuum that runs from 1 to 5 point scores awarded to a respondent for selecting from a choice of 1-5 possible answers to a specific question. The answers represent variable weights (e.g., low to high, bad to good etc) and directly correspond with the awarded point scores (Robinson 1998). The overall (total) score earned by a respondent would reflect his level of attitude toward certain behavioral issue; lower total score would indicate poor and rather negative attitude, and lower and unclear perception and awareness level, and high score would indicate his clear perception. The overall score can be used as an indicator of perception (Paul 2004). It can also be transformed into Z-score and the Z-values can be used as a perception index (Tucker and Napier 1998).

In this study, the Likert scale was employed for each behavioral question asked; the respondents were given an array of possible answers. Response to each question and other relevant information was carefully noted in the field note and later coded and input into the SPSS data file. The collected data were used to construct both human perception and participation indices as well as a number of human ecological and socio-economic-political variables that affect perception and participation levels of individual respondents. In the following sections, the definition of variables included in perception and participation indices, and the methods of construction of perception and participation indices are presented in details.

Construction of Human Perception Index

A human perception index was constructed on the basis of respondent answers to questions on knowledge about the symptoms of arsenic related diseases (S), sources of arsenic poisoning of humans (W), duration of knowledge acquired (T), and health threats of arsenic poisoning (K). Each question had multiple possible answers; and for each answer, 1-5 point score was awarded to the respondent in the following manner (Table 4).

1) **Perceived knowledge about symptoms of arsenic poisoning (S):** The respondent was asked to identify the symptoms of arsenic poisoning. He was given a list of five symptoms beginning with skin pigmentation up to severe cases of cancer (Table 4). One point was awarded for each symptom identified correctly, and 5 points were given for correctly identifying all five symptoms.

Question	Answer Choices	Assigned Points
What is your knowledge of arsenic poisoning and its health threats?	No threat	1
	Slight threat	2
	Moderate threat	3
	High threat	4
	Very high threat	5
Which of the following do you think are symptoms of arsenic poisoning?	Irritation in gastro-intestinal and upper respiratory tracts	Number of symptoms identified = number of points
	Light skin pigmentation	
	Keratoses	
	Skin, lungs, and pancreatic cancer	
How do you think arsenic might enter into your body?	No idea	1
	Pond water	2
	Dug well water	3
	Use of chemical/fertilizers	4
	Drinking contaminated tube well water	5
How long have you known about the potential health hazards related to arsenic poisoning?	Within 1 year	1
	1-2 years	2
	2-3 years	3
	4-5 years	4
	More than 5 years	5

Table 4: Types of variables used to calculate human perception score.

2) **Perceived knowledge about source of arsenic poisoning (W):** The respondent was asked about the source of arsenic ingestion or poisoning of human body. The responses varied from drinking pond water, dug well water, use of chemical fertilizers, and drinking tube well water. This difference in opinion was due to lack and ambiguity of knowledge, or just developed from circumstantial evidences, e.g., working with chemical fertilizer in rice field, or bathing and drinking in toxic pond water or dug well water that can cause skin lesion, itchy rashes which resembles like arsenic poisoning symptoms. In the scale of degree accuracy, answer such as 'no idea what causes it' would not merit anything; drinking pond water would be totally incorrect; dug well water is somewhat correct particularly in an arsenic enriched shallow aquifer; use of agro-chemicals is scientifically proven fact, therefore, weak but correct; and drinking contaminated tube well water is correct and the only expected answer. Based on the degree of accuracy, the respondent, therefore, was assigned 1 point for having no idea, 2, 3, 4 and 5 points for answering pond water, dug well water, use of chemicals, and contaminated tube well water respectively.

3) **Duration of knowledge acquired (T):** The respondents were asked about the number of years they have first known about arsenic contamination of drinking water and its harmful health impacts. Five points were assigned if the respondent first heard about it >5 years

ago, and 1 point was given if heard <1 year ago. Two, three and four points were assigned for first learning it 1, 2-3, 4-5 years ago (number of months were rounded up to the nearest year).

4) **Perceived health threats of arsenic poisoning (H):** The respondent was asked to rank his knowledge about the possible health threats of arsenic poisoning in a scale of 1 to 5, 1 being no threat, 2, 3, 4, and 5 representing slight, moderate, high, and very high threat respectively. Each respondent was awarded 1-5 point for the degree of severity of his perceived threat level.

For each respondent, points earned for answering all four questions were added to obtain an overall Human Perception Score (HPS) as follows.

$$\mathbf{HPS = (S + W + T + H)}$$

The value of HPS would range from 4 to 20. Respondents earning low HPS scores presumably would have low perception about arsenic hazard than those who scored high scores.

Construction of Individual Participation Index

An index of individual participation in mitigation action was constructed using the responses to the questions related to perceived method of mitigation, degree of willingness to participate, mode of participation, and monetary contribution one pledged to make (Table 5). Each response was scored in the following manner.

Question	Answer Choices	Assigned Points
Which of the following do you believe is a viable mitigation option for treating arsenic contaminated drinking water?	Deep tube well water	Two points were awarded for choosing 1 solution, 4 points for choosing 2 solutions, and 5 points for selecting 3 solutions
	Rain Water	
	Three bucket filtration system	
Are you willing to participate in community based arsenic mitigation activities	Not wiling to participate	1
	Slightly willing to participate	2
	Moderately willing to participate	3
	Willing to participate	4
	Very willing to participate and would do everything to mitigate arsenic poisoning	5
If you would like to participate in a community based mitigation process, how would you like to do so?	Assist in research organizations	1
	Sponsor a project	2
	Contribute money	3
	Publicize and educate people	4
	Carry water from arsenic free tube wells to neighborhoods	5
How much monetary contribution are you willing to make?	Up to Taka 100	1
	Taka 101-200	2
	Taka 201-300	3
	Taka 301-400	4
	More thank Taka 400	5

Table 5: Types of variables used to calculate individual participation score.

1) **Perceived methods of mitigation of arsenic hazard (M):** In order to ascertain how well the respondent was informed about the treatment of Arsenic patients, removal of arsenic from drinking water, and mitigation of the Arsenic hazard, he was given a list of three solutions to choose from (Table 5). Two points were awarded to respondent answering one solution; 4 points for 2 solutions, and 5 points for mentioning all three solutions.

2) **Willingness to participate in arsenic mitigation activities (E):** A respondent was asked whether he was willing to participate in community based arsenic mitigation activities. He was asked to specify his degree of eagerness in the scale 1 to 5; 1 being not eager to participate and 5 for willing to do everything to mitigate arsenic poisoning. Accordingly, a respondent was assigned 1 to 5 point score.

3) **Nature of participation (N):** The respondent was given four possible ways he can participate in the mitigation process, they are, assist research organizations, sponsor a project, contribute money, and publicize and educate people. One to four point scores were assigned to a respondent depending upon the number of ways he was willing to participate, and 5 points was given to anyone who would do everything possible to mitigate arsenic poisoning.

4) **Monetary contribution to the mitigation action (DO):** A respondent was asked how much he would be willing to contribute in the

mitigation process. He was awarded 1 point for contributing ≤Taka 100, 2 for Taka 101-200; 3 for Taka 201-300, 4 for Taka 301-400, and 5 for >Taka 400.

For each respondent, points earned for answering all three questions were added to obtain an overall Individual Participation Score (IPS) as follows.

$$IPS = (M + E + N + DO)$$

Again the value of IPS would range from 5 to 20; respondent earning less than 10 (<50%) points would have low participation rate; 10-15 (50-75%) points would have moderate participation, and 15-20 (75-100%) points would have high participation rate in the mitigation of arsenic hazard.

Factors Affecting Human Perception and Participation Decisions

To examine the impacts of various socio-economic-institutional, and human ecological factors on individual perception of arsenic poisoning and participation in its mitigation action, the following information was gathered to define a set of human ecological and socio-economic-political variables.

Socio-Economic-Institutional Variables

1) **Occupation:** The respondent was asked about his occupation and the answer was recoded in nominal scale: 1 represented wage laborers, 2 represented farmers, 3 represented industrial workers, 4 represented businessmen, and 5 represented professionals, government and NGO

employees. This variable was used only for t-test as categorical variable, and not included in correlation and regression analyses.

2) **Farm size:** The respondent was asked to report his household operation (own and lease) of land in ha.

3) **Level of education:** The respondent was asked report the number of years he attended academic institutions for formal education. Five years of schooling would indicate that the respondent has elementary education; 10 years of schooling would mean he has graduated from high school; 14-16 years of education would indicate the respondent has bachelors to master's degree.

4) **Monthly income:** The respondent was asked to report household monthly income in taka from all farm and non-farm sources.

5) **Institutional affiliation:** The respondent was asked about his affiliation to local government, political parties, NGOs, research and development organizations working on arsenic hazard in the village. Answers to this question was awarded 1 point for no affiliation, 2, for his affiliation with one or more organizations. This is categorical variable included in t-test but not in regression statistics.

6) **Institution presenting/evaluating the arsenic hazard information:** The respondent was asked about the sources of his information about arsenic hazard. He was awarded one point for learning it from either friends or relatives or neighbors; and two points for learning it from

both the sources. Three, four and five points given to him for learning it from one, two, and all three of the following sources: government, and NGO health workers, and University research groups. This was justified because information received from more sources, in general, and official sources, in particular, merit higher points due to their accuracy. Given its categorical or nominal nature, this variable was not included in regression statistics.

Human-Ecological Variables

7) **Access to information media:** The respondent was asked to report any ownership or access to information media such as radio, television, and newspaper covering news and research articles about arsenic hazard. Respondent with access to all three information sources was awarded 5 points, 4 points for any two sources, and 2 points for any one given source.

8) **Physical evidence of arsenic hazard:** The respondent was asked if he directly observed, suffered or nursed any arsenic patient in the family. If he answered yes, then he was asked for how many years he has been with a patient. He was awarded 1 point only for observing a patient in the neighborhood for ≤1 year; 2, 3, 4, and 5 points if directly observed and nursed patients in the family for a period of ≤1 year, 1-3 years, 4-5 years, and >5 years respectively.

9) **Perceived benefits of arsenic mitigation action:** The respondent was asked about his view on the benefits of arsenic mitigation action. He was awarded 1 point for answering 'not beneficial', 2, 3, 4, and 5 for answering very low beneficial, low beneficial, moderately beneficial, highly beneficial.

10) **Confidence in government actions.** Respondent confidence in government arsenic mitigation actions was measured using the scale of 1 point score for no confidence, 2, 3, 4, and 5 points for having very low, low, moderate, high, and very high degree of confidence.

11) **Physical proximity to arsenic hazard** was measured in terms of distances traveled by the respondents in meters to collect water from arsenic contaminated tube well.

Analytical Methods

The study entails two stages of analyses: 1) examination of the relationships between socio-economic and political variables and the perception index, and 2) assessment of the impacts of perception index on the decision making for mitigation action. The over all human perception scores (HPS) were transformed into standard z-scores to compute the human perception index (HPI). The index values (z-scores) ranged from –2.5 to +2.5, with negative (-) values being low or negative perception and positive (+) values being an indicator of high perception.

Both bivariate correlation and multiple regression statistics were employed to examine the effect of human-ecological, and socio-economic and institutional factors on the variation of human perception index. Several independent variables, such as political affiliation, institution presenting and/or evaluating the arsenic hazard, and perceived benefits of mitigation options, and confidence in government action were categorical in nature while other independent variables were continuous. Two-sample differences of mean tests (t-test) were employed to assess the crude effects of categorical independent variables on the dependent variable, human perception index (HPI). On the other hand, Pearson's correlation analysis was used to explore the effect of continuous independent variables on the dependent variable.

To examine the overall effect of all human-ecological, socio-economic factors on the perception index, a multiple regression statistic was employed using the perception index as a dependent variable, and farm size, education, income, literacy, access to information media, physical evidence of hazard, perceived benefit of mitigation action, number of years patient suffering in the family, confidence in government mitigation action, and proximity to the hazardous area as independent variables. Categorical variables such as occupation, institutional affiliation of the respondent, and institution evaluating the hazard information were not included in the multiple regression analysis. However, their influence on human perception was examined using the student t-test. Both the t-test and bi-variate correlations coefficients were used to test the hypothesis 1. Using the Pearson's correlation analysis tested hypothesis 2 depicting the relationship between perception index and the participation index. Values of the regression coefficients and the Pearson's correlation coefficients are both expected to be high and statistically significant indicating strong relationships between the variables.

CHAPTER IV

PEOPLE'S AWARENESS & PERCEPTION OF ARSENIC HAZARD

Characteristics of Sample Respondents

Field work for this study has generated large volume of household data on various socio-economic conditions of 148 sample respondents, as well as their perception of arsenic hazard and participation in its mitigation processes. In the section, these background characteristics of sample respondents are briefly presented to better understand their perception and behavioral patterns toward arsenic hazard. It was revealed that large percentage (74%) of sample respondents were small-medium land-holders (≤3 ha) who attended elementary and high school and engaged in farming and work off-farm as wage laborers, and earn less than Taka 5,000 per month. Respondents (10%) had higher education and were engaged in businesses and governmental and NGO employed salaried jobs.

The socio-economic conditions of the respondents varied among the villages. In Rajarampur, for example, 60% of the respondents were small-medium holders, attended elementary and high schools, engaged in farming and worked off-farm as wage laborers, and earned less than Taka 5,000 per month.

In Bakaborshi, 84% of the respondents were small-medium holders who attended elementary and high schools, engaged in farming and worked off farm as wage laborers, and earned less than Taka 5,000 per month. In Samta, 75% of the respondents were small-medium land-holders who attended elementary and high schools, engaged in farming and wage labor jobs, and earned less than Taka 5,000 per month. When compared by the farm size and income, respondents of Bakaborshi village is poorer than the respondents from other two villages under study.

All the respondents reported to have linkages with one or more of the institutions working on arsenic problems. Thirty percent of the respondents received information and arsenic mitigation assistance from the government public health departments; 67% received assistance from various NGOs and village development agencies; and only 3% were involved with and received support from research organizations working on the arsenic problem. Since there were alarming numbers of arsenic patients, all three villages received wide attention from the government public health department, NGO, village development agencies, national and international research organizations.

The respondents also had variable access to information media advertising the hazardous impacts of arsenic contamination of drinking water. About 39% respondents did not own any information media such as radio, television; neither had they subscribed to any newspapers. This group of respondents learned about the hazard from their neighbors and friends who had arsenic patients in their families and from village doctors and local health workers who treated the patients in their neighborhood. They also listened to radio, television and read newspaper articles from their neighbors who had these information sources. Thirty percent of the respondents owned either a radio or a television or subscribed regularly to a newspaper. This group of respondents learned about the arsenic hazard directly from listening to radio and television reports and newspaper articles at home and took the advantage of sharing the information with their neighbors. The remaining 31% had access to multiple sources of information, which included radio, television, and newspaper subscription, and were perhaps the best informed members of the sample. The sampled respondents have been a true representative of variable socio-economic conditions, which would very well configure their awareness and perception level of the hazard posed by arsenic contamination of drinking water.

Developing Awareness and Perception of Arsenic Hazard

The incidence of arsenic contamination of drinking water has been the most widely-discussed natural hazard in Bangladesh in recent years. Most people in the country are now knowledgeable about the hazard and its impacts on human health. Likewise, most sample respondents in three villages knew about arsenic contamination of tube-well water and its harmful effects on human health. However, their individual level of awareness and perception varied with their source, accuracy, and duration acquiring the knowledge, socio-economic background, access to the information media, opportunity for direct observation of and exposure to an arsenic patient. It also varied with their level of understanding of the mechanism of arsenic contamination of tube well water, methods of its ingestion into human body, and its impact on human health. In this section, a perception index is constructed based upon the respondent's knowledge on these parameters.

1. *Knowledge of Symptoms of Arsenic Poisoning:* Regardless of their farm size, education and income level, or institutional affiliation, respondents from all three villages knew that most tube well water in their localities contained large quantity of arsenic poison; and that drinking of arsenic contaminated water causes serious diseases leading to death (Table 6). When asked about "what is arsenic?" and "what are the symptoms of arsenic poisoning?", 31% of the respondents without any formal education, and 57% with high school, college and university education correctly mentioned dark skin spots (pigmentation), skin lesion, keratoses, skin, lungs, and pancreatic cancer are the main symptoms of arsenic poisoning. Only 4% of the respondents, most of whom are poor small holder farmers and daily wage laborer with very little or no schooling (<5 yrs.) had very little or no knowledge about it. This latter group viewed arsenic poisoning can cause stomach irritation, cough and chest skin irritation and light pigmentation. Similarly, 88% of the respondents regardless of their income identified the correct symptoms of arsenic poisoning.

Indicators of Perception of Arsenic Hazard	Expected Response	Farm Size			Years of Schooling				Monthly Income in Taka				Institutional Affiliation	
		Small	Medium	Large	<5	5-10	>10	Graduate College	1-2,500	2,501-5,000	5,001-10,000	>10,000	No	Yes
Which of the following do you think are symptoms of arsenic poisoning?	Irritation in intestinal and upper respiratory tracts	3 (2)	1 (1)	1 (1)	1 (1)	2 (1)	1 (1)	1 (1)	1 (1)	1 (1)	2 (1)	0 (0)	1 (1)	4 (3)
	Light skin pigmentation	7 (5)	5 (3)	2 (2)	6 (4)	3 (2)	5 (3)	0 (0)	4 (3)	8 (5)	2 (1)	0 (0)	4 (3)	10 (7)
	Dark skin pigmentation	6 (4)	3 (2)	2 (1)	3 (2)	4 (3)	4 (3)	0 (0)	3 (2)	5 (3)	1 (1)	1 (1)	1 (1)	10 (7)
	Keratoses	28 (19)	23 (16)	21 (14)	29 (20)	15 (10)	21 (14)	7 (5)	20 (14)	30 (20)	12 (8)	10 (7)	24 (16)	48 (32)
	Skin, lungs, and pancreatic cancer	26 (18)	8 (5)	12 (8)	14 (9)	19 (13)	8 (5)	5 (4)	12 (8)	22 (15)	5 (3)	7 (5)	15 (10)	31 (21)
How do you believe arsenic entered your body?	No idea	3 (2)	1 (1)	1 (1)	3 (2)	0 (0)	2 (1)	0 (0)	1 (1)	3 (2)	1 (1)	0 (0)	1 (1)	4 (3
	Pond water	1 (1)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
	Dug well water	3 (2)	0 (0)	2 (1)	2 (1)	1 (1)	2 (1)	0 (0)	1 (1)	4 (3)	1 (1)	0 (0)	1 (1)	4 (4)
	Use of chemicals/fertilizers	2 (1)	2 (1)	3 (2)	3 (2)	3 (2)	1 (1)	0 (0)	1 (1)	4 (3)	2 (1)	0 (0)	0 (0)	7 (5)
	Contaminated tube well water	61 (41)	40 (27)	29 (20)	44 (30)	39 (26)	34 (23)	13 (9)	36 (24)	57 (39)	19 (13)	18 (12)	42 (28)	88 (59)
How many years have you known about the arsenic problem?	1 year	12 (8)	1 (1)	0 (0)	8 (5)	5 (3)	0 (0)	0 (0)	8 (5)	5 (3)	0 (0)	0 (3)	5 (3)	8 (5)
	2 years	16 (11)	5 (5)	3 (2)	16 (11)	5 (5)	3 (2)	0 (0)	16 (11)	4 (3)	2 (1)	2 (1)	13 (9)	11 (7)
	3 years	29 (20)	24 (16)	9 (6)	22 (15)	22 (15)	12 (8)	6 (4)	12 (8)	36 (24)	5 (3)	9 (6)	21 (14)	41 (28)
	4 years	7 (5)	7 (5)	17 (11)	6 (4)	5 (3)	18 (12)	2 (1)	3 (2)	13 (9)	13 (9)	2 (1)	6 (4)	25 (17)
	5 years	6 (4)	3 (2)	9 (6)	1 (1)	6 (4)	6 (4)	5 (3)	1 (1)	10 (7)	2 (1)	5 (3)	0 (0)	18 (12)
What is your perception about arsenic?	No threat	4 (3)	2 (1)	1 (1)	4 (3)	1 (1)	2 (1)	0 (0)	2 (1)	4 (3)	1 (1)	0 (0)	2 (1)	5 (3)
	Slight threat	4 (3)	4 (3)	1 (1)	3 (2)	2 (1)	3 (2)	1 (1)	3 (3)	3 (2)	2 (1)	1 (1)	3 (2)	6 (4)
	Moderate threat	5 (3)	5 (3)	4 (3)	4 (3)	4 (3)	6 (4)	0 (0)	4 (3)	7 (5)	3 (2)	0 (0)	4 (3)	10 (7)
	High threat	23 (16)	17 (11)	9 (6)	20 (14)	14 (9)	13 (9)	2 (1)	17 (11)	23 (16)	7 (5)	2 (1)	17 (11)	32 (21)
	Very high threat	36 (24)	12 (8)	21 (14)	22 (15)	22 (15)	15 (10)	10 (7)	14 (9)	31 (21)	9 (6)	15 (10)	19 (13)	50 (34)

Table 6: Perception about arsenic based on socio-economic conditions.

Most respondents with better access to information media such as radio, television and newspaper had better descriptions about the symptoms of arsenic poisoning (Table 7). Most respondents received the information from NGO workers (58%), government health workers (7%), and university/research organizations. Respondents who identified most severe symptoms e.g., keratoses, and skin cancers, learned about them from NGOs and research organizations. Respondents who lived closer to the arsenic contaminated tube wells had better awareness about the arsenic poisoning. Over 80 respondents who identified the symptoms correctly lived within 100 meters from the contaminated tube wells and collected drinking from them. Respondents who observed the patients closely as nearest neighbor or nursed them as family members, best described the symptoms compared to those who heard about the diseases. Again, respondents who observed the patients for short period of time (<1 yr), could describe only the early stage symptoms of arsenic poisoning such as skin spots and skin irritations.

2. ***Understanding the Source of Arsenic Ingestion in the Human Body:*** How did the naturally occurring arsenic entered into the human body to cause skin diseases has been a question asked to the respondents. This question purported to examine the respondent's level of understanding about the source and process of ingestion of arsenic poison in their body. About 90% of the respondents from all occupation, education and income or farm size categories believed that arsenic entered into their bodies through contaminated tube-well water (Table 6).

Indicators of Perception of Arsenic Hazard	Expected Response	Access to Media				Institution Evaluating Hazard					Physical Proximity to Arsenic Hazard		Observation of Patients				
		Newspaper	Radio	TV	All 3	Neighbor	Govt Worker	NGO	Univ Res Groups	More Than One Answer	Within 100 m	Within 200 m	1 yr	2 yrs	3 yrs	4 yrs	5 yrs
What is your perception about arsenic?	No threat	4 (3)	1 (1)	1 (1)	1 (1)	0 (0)	2 (1)	1 (1)	4 (3)	0 (0)	7 (5)	0 (0)	3 (2)	0 (0)	1 (1)	0 (0)	3 (2)
	Slight threat	5 (3)	1 (1)	3 (2)	0 (0)	1 (1)	0 (0)	6 (4)	1 (1)	1 (1)	8 (5)	1 (1)	1 (1)	0 (0)	2 (1)	1 (1)	5 (3)
	Moderate threat	5 (3)	9 (6)	0 (0)	0 (0)	3 (2)	0 (0)	7 (5)	3 (2)	1 (1)	11 (7)	3 (2)	1 (1)	0 (0)	0 (0)	0 (0)	13 (9)
	High threat	20 (14)	14 (9)	13 (9)	2 (1)	10 (7)	2 (1)	30 (20)	7 (5)	0 (0)	44 (30)	5 (3)	4 (3)	4 (3)	1 (1)	9 (6)	31 (21)
	Very high threat	23 (16)	20 (14)	19 (13)	7 (5)	13 (9)	7 (5)	37 (25)	5 (3)	7 (5)	60 (41)	9 (6)	10 (7)	1 (1)	3 (2)	3 (2)	52 (35)
How many years have you known about the arsenic problem?	1 year	10 (7)	2 (1)	1 (1)	0 (0)	0 (0)	0 (0)	8 (5)	5 (3)	0 (0)	11 (7)	2 (1)	3 (2)	0 (0)	1 (1)	0 (0)	3 (2)
	2 years	16 (11)	5 (3)	2 (1)	1 (1)	4 (3)	7 (5)	8 (5)	2 (1)	3 (2)	21 (14)	3 (2)	1 (1)	0 (0)	2 (1)	1 (1)	5 (3)
	3 years	24 (16)	20 (14)	14 (10)	4 (3)	12 (8)	3 (2)	34 (23)	7 (5)	6 (4)	58 (39)	4 (3)	1 (1)	0 (0)	0 (0)	0 (0)	13 (9)
	4 years	3 (2)	13 (9)	13 (9)	2 (1)	2 (1)	0 (0)	24 (16)	5 (3)	0 (0)	24 (16)	7 (5)	4 (3)	4 (3)	1 (1)	9 (6)	31 (21)
	5 years	4 (3)	5 (3)	6 (4)	3 (2)	9 (6)	1 (1)	7 (5)	1 (1)	0 (0)	16 (11)	2 (1)	10 (7)	1 (1)	3 (2)	3 (2)	52 (35)
How do you believe arsenic entered your body?	No idea	3 (2)	1 (1)	1 (1)	0 (0)	0 (0)	1 (1)	0 (0)	4 (3)	0 (0)	5 (3)	0 (0)	2 (1)	0 (0)	1 (1)	0 (0)	2 (1)
	Pond water	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
	Dug well water	3 (2)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	2 (1)	0 (0)	5 (3)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	4 (3)
	Use of chemicals and fertilizers	1 (1)	3 (2)	3 (2)	0 (0)	0 (0)	0 (0)	6 (4)	1 (1)	9 (6)	5 (3)	2 (1)	1 (1)	0 (0)	0 (0)	0 (0)	6 (4)
	Contaminated tube well water	49 (33)	39 (26)	32 (21)	10 (7)	27 (18)	9 (6)	72 (49)	13 (9)	9 (6)	114 (77)	16 (11)	15 (10)	5 (3)	5 (3)	13 (9)	92 (62)
Which of the following do you think are the ymptoms of arsenic poisoning	Irritation of intestinal and upper respiratory tracts	3 (2)	1 (1)	1 (1)	0 (0)	1 (1)	0 (0)	1 (1)	2 (1)	1 (1)	7 (5)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	4 (3)
	Light skin pigmentation	7 (5)	3 (2)	3 (2)	1 (1)	1 (1)	2 (1)	6 (4)	5 (3)	0 (0)	8 (5)	1 (1)	3 (2)	0 (0)	3 (2)	1 (1)	7 (5)
	Dark skin pigmentation	3 (1)	5 (3)	2 (1)	1 (1)	3 (2)	0 (0)	5 (3)	2 (1)	1 (1)	11 (7)	3 (2)	3 (2)	0 (0)	0 (0)	0 (0)	8 (5)
	Keratoses	26 (18)	22 (15)	20 (14)	4 (3)	12 (8)	3 (2)	43 (29)	10 (7)	4 (3)	44 (30)	5 (3)	6 (4)	4 (3)	2 (2)	7 (5)	53 (36)
	Skin, lungs, and pancreatic cancer	18 (12)	14 (9)	10 (7)	4 (3)	10 (7)	6 (4)	26 (2)	1 (1)	3 (2)	60 (40)	9 (6)	6 (4)	1 (1)	2 (1)	5 (3)	32 (22)

Table 7: Perception about arsenic based on access to media, institution evaluating the contamination, distance, and observation of patients.

Only 5% of the respondents believed that arsenic ingested into their body during their handling of chemical fertilizers. Only four respondents from Rajarampur village mentioned that they used dug well water for drinking and cooking, and still got skin lesions and irritations resembling Arsenic poisoning. One simple explanation to this comment is that most dug wells in Rajarampur and Chapai Nawabganj district area are 20-30 meters deep where the fine aquifer sand contains high quantity of arsenic, and drinking such contaminated water can cause skin lesion symptoms. One respondent wage labor/farmer from Samta village pointed out that his family used pond water and still suffered from skin lesion symptoms. The research team working for this study verified his comments by looking at the pond and observed that the pond was being used for soaking jute and its water looked polluted. Interesting is the fact that two members of this respondent family are educated and has college degree. Remaining respondents (4%) knew that arsenic ingested into their body through drinking water but they were not sure how tube well or any drinking water source can be contaminated with arsenic poison. These respondents were wage laborers and farmers with minimum education, low monthly income and least access to the information media.

In general, virtually all sample respondents in the three villages understood that drinking arsenic-contaminated water from tube wells was the prime source of arsenic poisoning of the villagers although they did not clearly know the actual mechanism of it. Information media such a radio, television, and national and local newspapers published numerous articles and news reports on arsenic poisoning and its sources of ingestion into human body. Over 88% respondents learnt about the mechanism of arsenic ingestion into human body from radio and television programs as well as NGO and research workers those categorically displayed and explained the way arsenic is ingested through drinking of water collected from contaminated tube wells (Table 7). Again most respondents, who identified drinking contaminated water from tube well as the main source of arsenic poisoning, lived within 100 meters and collected water from the contaminated tube wells. Their attempts to test all tube wells in the villages reaffirmed high level of understanding of the potential source of arsenic in the human body. During the field survey, every respondent asked the research team whether our goal of this research was to test his tube well for arsenic contamination in order to provide arsenic free water supply.

3. *Duration of Knowledge of Arsenic Hazard:* Arsenic poisoning of drinking water became a public health hazard for more than 10 years. The first case of arsenic related skin lesion was detected in Rajarampur in 1995; in Samta in 1994; and in Bakaborshi in 1998. However, the symptoms of arsenic poisoning took its hazardous form during the past 5-6 years when virtually all villagers in the study areas became aware of the hazard. The majority (75%) of the respondents knew about the arsenic contamination of drinking water for over 3 years as more and more people get affected by the poisoning. Only few small holders (8%) are less educated (<5 yrs of schooling), and farmers and wage laborers, became aware of

the problem only last year (Table 6). Seventy percent respondents who knew about the problem over 3 years had linkage and affiliation with social institutions such as the government and NGO health workers, and research organizations who informed the villagers about the hazard. Comparatively wealthier respondents, viz., large farmers, businessmen and educated salaried employees with monthly income over Taka 5,000, with better access to information media and institutions learnt it much earlier than the other residents of the villages.

4) Perceived Health Threat of Arsenic Hazard: Since most villagers were knowledgeable about the symptoms of arsenic poisoning of humans, and they know the sources of such problem, it was appropriate to ask the respondents to describe the threat level posed by arsenic contamination of drinking water. Only 5% respondents viewed arsenic poisoning as no threat. This group of respondents were mostly small holder farmers and wage laborers with very little (<5 yrs of schooling) education, and low monthly income considered it as no threat because of minor skin irritation and lesions are very common among rural people. If they suffer from it, they cannot do much about it. Another 7% respondents recognized it as slight threat to human health; one-half of this group have better education (>10 yrs.), better income (>Taka 5,000), and better affiliations with the NGOs. Ten percent respondents identified arsenic poisoning as 'moderate threat' to human population. This group represented all farm size, education and income classes. One-third of the sample respondents reported that arsenic poisoning posed high threat to their lives as it causes more suffering leading to death. Majority of these respondents were small holder farmers, wage laborers, and educated low income groups with patients at primary stage of symptoms. Over 46% of the respondents representing all farm size, education and income classes viewed this as a very high threat to human life. It was observed that this group has suffered for long time and some of the family members were at very late stage of skin cancer, skin lesion, and keratoses. They have taken both modern and traditional treatment for the disease through various government, NGO and research teams working in three villages. Respondents who had listened and watched to radio, television programs, and read newspaper articles viewed arsenic poisoning as a very high threat to human life and identified it as a natural hazard since tube well water was a natural source. Respondents, who worked in NGO offices, assisted the research works, lived closed to contaminated tube well, observed and nursed patients, perceived arsenic poisoning as a very high threat to human lives.

Human Perception Index

Based upon respondent answers on the issues of arsenic hazard discussed above, an overall Human Perception Score (HPS) was computed by adding all the point scores earned by a respondent on each question asked. Only 5% respondents scored 10 points or less; 30% scored between 11-15 points; and remaining 65% scored more than 15 points. This indicates that majority of the respondents viewed arsenic as a major natural hazard to human health. To compute a human perception index, the overall HPS for all 148 sample respondents were transformed into standardized z-scores. For each respondent, z-score value was used as his index of perception toward arsenic hazard. Only 7% respondents had z-score < -1.51; 12% between -1.5 and -0.5; 53% between -0.5 and 0.5; 23% between 0.5 and 1.50; and 6% over 1.51. In this study, the answers to each questions asked to the respondents were scored from 1 to 5, in the scale where 1 and 5 indicated low and high in attitude spectrum. Low overall score or z-score, therefore, indicated low perception and high overall score and z-score indicated high perception about the arsenic hazard.

It was observed that most small holder farmers and wage laborers with little or no education and access to news media and with low income had low perception. Medium holder farmers and businessmen had shown somewhat moderate perception (z-score between -0.5 to +0.5) toward arsenic hazard. These respondents had elementary and high school education and had access to at least one information source and earned Taka 2,500-5,000 per month. Finally, most educated businessmen and salaried employees had the best perception (z-score > +0.51) to arsenic hazard (Table 8). Interestingly, among all occupational and socio-economic categories, respondents with arsenic patients in the family, i.e., who either suffered or had direct contact with the patients had the most accurate perception of the arsenic contamination of drinking water and its hazardous impacts on human health, which was expected. Educated employees and

Village	Perception Index in Z-scores (% respondent)	Occupation	Farm Sizes in Hectares	Income in Taka/Month	Years of Education	Years of Observing Patients in Family
Samta	<-1.51 (2)	Wage Laborers	< 1.5	< 2,500	< 5	< 2 – 3
	-1.50 to -0.51 (8)	Farmers	< 1.5	< 2,500	< 5	< 2
	-0.50 to +0.50 (26)	Farmers, Wage Laborers	1.5 – 3.0	< 5,000	> 10	< 5
	-1.50 to -0.51 (10)	Businessmen	> 3.0	< 7,500	> 10	< 5
	>1.51 (2)	Salaried Employees	< 3.0	> 10,000	> 10	< 5
Bakaborshi	<-1.51 (3)	Wage Laborers	< 1.5	< 2,500	< 5	< 2
	-1.50 to -0.51 (4)	Wage Laborers	< 1.5	< 5,000	< 5	< 1
	-0.50 to +0.50 (29)	Farmers, Wage Laborers	< 1.5 – 3.0	< 5,000	> 10	< 5
	-1.50 to -0.51 (12)	Farmers	> 3.0	< 7,500	> 10	< 5
	>1.51 (2)	Businessmen	< 3.0	< 10,000	> 10	< 5
Rajarampur	<-1.51 (6)	Wage Laborers	< 1.5	< 2,500	< 5	< 1
	-1.50 to -0.51 (6)	Wage Laborers	< 1.5	< 2,500	< 5	< 2
	-0.50 to +0.50 (24)	Businessmen, Salaried Employees	1.5 – 3.0	< 5,000	< 10	< 3
	-1.50 to -0.51 (12)	Businessmen	< 3.0	< 7,500	> 10	< 5
	>1.51 (2)	Businessmen	> 3.0	> 10,000	> 10	< 5

Table 8: Human perception index and socio economic conditions of the respondents.

businessmen with better access to the information media also had better perception about the problem.

In all three villages, small holders and wage laborers with little or no education and poor access to information media, had the lowest overall perception score and index value ($z<-1.51$). In Samta and Bakaborshi villages, both farmers of all farm size categories, and wage laborers with high school education had moderate human perception index values (z from -0.50 to 0.50). In Rajarampur, both businessman and salaried employees had this level of z-scores. In Rajarampur and Bakaborshi, businessman had the highest perception score ($z>1.51$), whereas in Samta, well educated salaried employees had this type of high perception scores and index values. In general, all respondents from three villages had much better perception of arsenic hazard compared to other part of the country because of on-going research projects conducted by a Japanese, British, American university research teams who worked with the villagers to increase awareness and provided monetary and medical aids to victims as well as installed deep tube-wells to supply pure drinking water to the villagers. Because of this event, villagers became quite knowledgeable about arsenic contamination in the tube-wells and its health effects and considered it as a major problem in the village.

Factors Affecting the Level of Perception of Arsenic Hazard

A Bi-variate Assessment & Testing of Hypotheses

Both t-test and Pearson's correlation analysis results show very interesting relationships between human perception index and the selected human ecological and socio-economic-institutional characteristics of the respondents. The t-tests of categorical variables suggest that there were significant differences in individual perception of arsenic hazard among respondents with different occupational background, institutional affiliation, institutions presenting and evaluating the hazard information (Table 9).

The correlation coefficients between the human perception index (dependent) and farm size, education, income, access to media, physical evidence of arsenic, and perceived benefits of mitigation action appeared to be positive and significant. On the other hand, there appeared significant negative relationship between human perception index and proximity to the arsenic contaminated tube wells, and confidence in government arsenic mitigation actions. These findings provide scopes of acceptance of hypothesis 1.

A Multivariate Assessment

The level of human perception to natural hazard can be configured for both human ecological and socio-economic-institutional conditions in which the individual live and operate. In the earlier section, the analysis of both individual and three villages aggregate data suggests that the human perception of arsenic

	Name of Variable	Name of Statistical Test Performed	Results
Categorical Data Variables	Occupation	T-Test	324.58 (<0.0001)
	Political affiliation		44.70 (<0.0001)
	Institution presenting hazardous information		22.58 (<0.0001)
Continuous Data Variables	Farm size	Pearson Correlation	0.361 (<0.0001)
	Education		0.75 (<0.0001)
	Income		0.69 (<0.0001)
	Access to the media		0.73 (<0.0001)
	Physical evidence		0.65 (<0.0001)
	Distance traveled		0.55 (<0.0001)
	Perceived benefits		0.69 (<0.0001)
	Confidence in government and validity of social actions		-0.33 (<0.0001)

Table 9: Types of statistical tests performed and their results.

hazard varies with the socio-economic conditions of the household and their linkage with the information media as well as outside research and NGO activities. It was not, however, clear which of the socio-economic-institutional variables has greater or lesser impact on the development of perception. It was not clear whether the various human ecological parameters identified earlier in the conceptual framework underlying this study have at all any impact on the development of perception. This section of the study is, therefore, devoted to examine the impacts of both human ecological and socio-economic-institutional variables on the development of human perception of natural hazard caused by arsenic contamination of drinking water in the villages under study.

In this study, the human perception index constructed earlier was taken as the variable dependent on a set of eight selected independent human ecological and socio-economic-institutional variables. At the initial stage, multiple regression analysis of eight independent variables on the perception index yielded an adjusted R^2 of 0.813 indicating that selected variables explained 81.3% of the total variation of human perception (Table 10). Respondent education, monthly income, presence of arsenic poisoned patients in the family emerged as the strongest predictor of human perception followed by the perceived benefit of arsenic mitigation action, access to information media, and farm size variables. Proximity to arsenic contaminated tube well had significant negative influence on perception index. This was expected because respondents living closer to the contaminated tube well were much more aware about the arsenic hazard and

$Y = -0.300\, x_1^* - 0.250\, x_2^* + 0.182x_3^* + 0.178x_4^* + 0.160x_5^* + 0.126x_6^* + 0.110x_7^* + 0.080x_8^*$		
Adjusted coefficient of determination (R^2) = 0.813 Y = Perceived risk from arsenic contamination	Mean	Std. Deviation
x_1 = Distance traveled to collect water for daily use	86 m	45.01 m
x_2 = Confidence in government arsenic mitigation action	2.37	1.18
x_3 = Household monthly income	Taka 3,777	Taka 2,442
x_4 = Access to information media	2.57	1.27
x_5 = Information relating to physical evidence of patient	3.30	1.47
x_6 = Level of education	3.21	1.34
x_7 = Perceived benefits of mitigation action	2.66	1.45
x_8 = Household farm size	2.36 ac.	3.27 ac.
*Variables significant beyond the 0.05 level		

Table 10: Results from the initial regression model.

vice versa. Confidence in government mitigation action was found to exert negative influence on human perception. This is because of the fact the government health department workers are less active in mitigation efforts compared to the NGOs and research groups. The latter two groups provide free medication and water purification devices and also educate people about the hazard.

From correlation coefficients, it was found that socio-economic variables such as farm size, years of education and monthly income are highly inter-correlated and their presence in the multiple regression models could cause higher degree of multi-colinearity. It was rational to assume that both farm size and education can strongly affect household monthly income. And selection of household income alone should well demonstrate the impact of farm size, occupation and education. However, education may show high degree of correlation with income, but it significantly affects respondent's ability to interpret the information of the risk of arsenic hazard. In this study, therefore, level of education and monthly income were the two socio-economic variables selected for multiple regression analysis.

At the final stage of analysis, multiple regression statistics of 7 independent variables surprisingly have explained 81% (adjusted $R^2 = 0.81$) of the variation in the human perception of arsenic hazard among the residents in the study villages (Table 11). Three variables such as household income, education and presence of arsenic victim patients have emerged as the most

$Y = -0.290\, x_1^* - 0.240\, x_2^* + 0.194 x_3^* + 0.180 x_4^* + 0.173 x_5^* + 0.138 x_6^* + 0.140 x_7^*$		
Adjusted coefficient of determination (R^2) = 0.81 Y = Perceived risk from arsenic contamination	Mean	Std. Deviation
x_1 = Distance traveled to collect water for daily use	86 m	45.01 m
x_2 = Confidence in government arsenic mitigation action	2.37	1.18
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x_4 = Access to information media	2.57	1.27
x_5 = Information relating to physical evidence of patient	3.30	1.47
x_6 = Level of education	3.21	1.34
x_7 = Perceived benefits of mitigation action	2.66	1.45
*Variables significant beyond the 0.05 level		

Table 11: Results from the final regression model.

important predictors of human perception to the arsenic hazard. Both proximity and confidence in government action variables still exerted negative influence on human perception index.

CHAPTER V

PARTICIPATION IN ARSENIC HAZARD MITIGATION

Mitigation Options Available in the Study Areas

Since the three villages selected for this study had high risks of arsenic hazard and had large number of patients, they have drawn considerable interest from both national and international researchers and NGOs. In Rajarampur, for example, both faculty and researchers from the University of Rajshahi have set up research stations and has conducted experiments with several water purification methods including collection of rainwater and treatments of pond and surface water. In both Samta and Bakaborshi, where large numbers of patients have been suffering from worst health hazard, several Japanese research teams have been continuously monitoring the situation, experimenting the ground water sources of arsenic, and providing vitamin supplements and deep tube wells for arsenic free water supply to the villagers.

Despite all the help received by international and national organizations, mitigation and prevention processes are still inadequate to save millions of people in the country, and thousands in the study villages. A permanent arrangement to purify water and mitigate arsenic contamination was felt to be at high demand in the study villages. In all three villages, people were asking whether research will help them to receive better mitigation and preventive actions or not. Due to lack of government and NGO resources to provide adequate supply of arsenic free deep tube wells, both government and NGOs encouraged private arrangements to mitigate arsenic from tube well water which involved both voluntary participation in group mitigation projects, making monetary contributions, and assisting research workers to find out easy low cost mitigation solutions.

The present study attempted to explore villagers' level of participation in those mitigation options. At the household level, it was observed that despite their adequacy in knowledge of the arsenic contamination of drinking water drawn from the household tube wells, and its harmful effects on human health, higher percentage (>50%) of farming and business family households still used contaminated water. They believed that there was no harm using it, or they had no alternate source of drinking water, and their tube well water was not adequately tested, so there was reasonable doubt about the level of contamination. Interestingly and to the contrary, less than 40% of wage earners and service holder households used contaminated water. This variation was attributed to two circumstances. First, the wage-earning poor households did not have their own tube-well at home; they collected water from neighbor's tube-wells; and they had the opportunity to use the tube-well that was not contaminated or less contaminated. Either the farming and business households did not have this opportunity or they did not use it because of family prestige concern. Second, for the salary holder households, they had better opportunity to either purify or use alternate sources of water.

A very high percentage of sampled respondents in all three villages regardless of their occupational and socio-economic conditions, and with or without an arsenic victim patient in their families had knowledge about water purification and various arsenic mitigation procedures and options. Some of the common arsenic mitigation options known to all respondents were water filtering, use of deep tube well water, collection and use of rainwater, and the uses of ponds and well water. Over 80% of the respondents in all three villages knew that water filtering and the use of deep tube wells are the safest methods of arsenic mitigation. Less than 10% knew that open surface water such as pond, well, and rainwater should be arsenic free; regardless, they resisted using these sources for drinking and cooking because of the possibility of some other type of contamination. This situation also differed by socio-economic conditions of the respondent households. It was observed that about 40% of respondent household in each of four occupational classes knew about water filtering; 40% knew about deep tube well as a source of arsenic free drinking water; only 10% knew about both the option. Only 10% of farmers, businessmen and wage laborers, and 81% of salaried employees had known the fact that rain, pond and well water of being arsenic free. Education level and monthly income had very strong influence on the knowledge of arsenic mitigation methods. Very high percentage of respondents with different education level and income, knew that water filtering and deep tube well water should mitigate the arsenic problem.

Virtually all respondents, regardless of their socio-economic conditions, as well as risk and perception levels, preferred to receive more government and NGO support to address the arsenic contamination. However, they were also willing to participate in the mitigation projects despite the possibility of their monetary involvement in such projects. Some respondents would prefer to pay the cost of arsenic mitigation as per their financial ability; about 20% of respondents were willing to pay up to Taka 200 per month to receive arsenic-free water and a few rich service and businessmen households were willing to spend as much as Taka 500 or more per month for the safer drinking water supply. Poor, less-educated, and farming and laborer respondents preferred not to pay and insisted that the government and NGO should take more responsibility to assure the supply of arsenic-free water for the country.

Participation Index

In order to explore the level of participation in the mitigation projects, sample respondents were asked to respond to the questions such in which way the respondent would participate and how much money (s)he would b willing to spend on water purification methods if government and NGO assistance were not available. The responses on the levels (mode) of participation, such to volunteer manual labor to install deep tube wells, assist research and experiments, and willingness to spend certain amount of money to buy mitigation devices were ranked and the scores were added and standardized in z-score to compute the participation index for the sample respondents. The participation indices of all three villages portray interesting results. It is observed that respondents with low or negative Z-scores (<-1.51) are primarily wage laborers who have very little education and low income (< Taka 2,500) and they don't have any access to information from the media. These groups of respondents also do not like to commit to any monetary contribution, but rather they prefer to help in the local and international research organizations. If it is made mandatory for them to contribute monetarily, they are willing to spend up to Taka 100 but do not want to get into any kind of contract. People with slightly negative or slightly positive Z-scores are primarily farmers (but there are few businessmen in this category) who have primary and some high school education and earn between Taka 2,500-5,000 per month. Because of their improved financial condition, they are willing to spend up to Taka 200. Since, they also have access to radio and/or newspaper, they have better knowledge about arsenic and its health hazards, and they willing to spread the word about arsenic to their family and neighbors as part of community mitigation project. Finally, people with high positive Z-scores, are mostly small business owners or servicemen who have high school diploma or college degree. Their monthly income exceeds Taka 5,000 and they would agree to pledge monthly monetary donation of up to Taka 300. However, because of their busy schedule, they are hesitant about talking to their friends and neighbors about arsenic.

Factors Affecting Participation Decisions

It was observed that participation decision varied greatly with the level of individual perception. Households with better education, higher income and obviously better access to the information media and thereby high level of perception to the arsenic hazard were most willing to participate in both individual and group (community based) mitigation process. Farmers and wage earners with low income and poor access to the information preferred either to accept more government and NGO assistances or refrain from monetary contributions. When correlated, participation indices showed strong positive ($r = 0.48$) correlation with the perception indices. This finding demonstrates that high perception would motivate and induce individuals to participate more in the mitigation options. This finding led us to assume that those human ecological and socio-economic-political variables that influenced strongly to build human perception to arsenic hazard in the study areas were inducing individual villagers to participate in the mitigation processes.

CHAPTER VI

SUMMARY AND CONCLUSION

This study reveals that various human-induced factors were responsible for arsenic contamination of tube well water on which very high percentage of people of Bangladesh relies for drinking water. Regardless of their causes, it was observed that a greater percentage of tube wells in the three selected villages under this study have been contaminated with arsenic to very high level which is hazardous to humans. Levels of arsenic contamination varied among the villages. Within the villages, not every tube well was contaminated at the same level. This variation within and between villages is probably due to the depth of underground water level from which the tube wells were drilling water as well as the composition of the bedrock underlying the surface.

The study results reveal that two (Samta and Rajarampur) of three villages under study have very high risk of arsenic hazard as indicated by high concentration of arsenic in tube wells as well as high number of victims per 1,000 people. Bakaborshi had a moderate level of arsenic because of lesser concentration of arsenic in tube well water and fewer victims. One thing that becomes clear from this study is that a very large percentage of Bangladeshi population is now vulnerable to a greater risk of arsenic hazard, which is more prominent in some places than others as revealed from British Geological Society surveyed water quality test results for the entire country. The villages that are still in a low risk profile may face a greater risk in future if the process of arsenic release in tube well water was not stopped and/or its presence in drinking water was not mitigated through water purification methods. Because over a long period, tube well water has been considered by most rural population as the easiest, most reliable and least cost supply of safe drinking water in Bangladesh. For this reason, despite being aware of the presence of arsenic in their tube wells, many people continue to use them because there is no other easy alternative and people believe that there is no harm using less contaminated water. This vague and inaccurate perception of the problem may push more people toward even much greater risk because slower build up of arsenic in human blood stream over time due to drinking of less arsenic contaminated water may also cause similar harmful effects as is done by high contaminated water- a hypothesis yet to be tested in clinical experiments.

The study results suggest that peoples' awareness about arsenic contamination has increased as more and more information about the hazard became available through radio, television and news media as well as direct experience from the victims either in the family or in the neighborhood. However, that awareness is not even adequate and varied among various occupational groups and their socio-economic conditions. The least informed and less perceived people are the poor farmers and wage laborers, and low-income and least educated businessmen, who did not have access to the information sources. Among the villagers, higher degree of awareness and perception of arsenic hazard was found among the victim families and their immediate neighbors, and among the educated, high-income service holders who had better access to various information sources and had a wide scope of direct observations. The study findings demonstrate that respondents with higher education level, better income, adequate access to the information sources and those having patients in the family had better perception level than their others. These findings provide support to accept the hypothesis 1 tested in this study.

It is also revealed in this study that most villagers were aware of the arsenic mitigation process and their availability in the villages. However, respondents with higher perception of the arsenic hazard were better prepared and most willing to participate in the mitigation process. This finding provides strong support to hypothesis 2 and demonstrates that development of awareness is key force inducing people to participate in the mitigation process.

It was also evidenced during the study that despite their knowledge of on-going mitigation efforts, many people continued to drink the arsenic contaminated tube well water simply because of their ignorance of the future consequences, or otherwise there is no other alternative available to them. It was also observed that at the current state of the hazard, both government and NGOs in Bangladesh have been very busy in testing the level of contamination, which is even inadequate compared to the need. Some misleading water test results (for example, those by the BGS) were also published and were taken as a basis of policy implications. These highly controversial results frightened both the rural and urban population alike. However, when the actual merit of that controversial report was disclosed and challenged by the local researchers through recent water test results, the importance of the problem was significantly diminished particularly among the rural poor who could not afford to bear the cost of mitigation and were totally confused by these contradictory results.

Another interesting issue discovered during this research is that the villagers are to a large extent frustrated because of the performance of the government, compared to NGO and researcher activities. They were interviewed repeatedly by many researchers from home and abroad and were given high level of assurance and false hopes that a significant water mitigation effort was under way. Once the research team is gone, villagers' hope evaporated as the time passed by or unless another research team shows up. This has increased the frustration among the villagers who then decided to continue drinking the contaminated water regardless of its hazardous impacts.

The rural society responded to the arsenic mitigation projects in a positive way. Virtually all respondents and the villagers at large were eager to get arsenic free water and were ready to cooperate with the research team to find out a cheapest possible means of water purification. They were willing to bear the cost of arsenic mitigation devices if that is within their capacity. However, most villagers agreed that the government of Bangladesh should take greater responsibility, and undertake more active research on mitigation process than the public. They believed that without the government intervention and international cooperation to build large-scale water purification facilities to assure arsenic free drinking water supply in the rural areas, the country may lead to the largest mass poisoning in human history.

APPENDIX I

ARSENIC CONTAMINATION SURVEY QUESTIONNAIRE

District: ____________________Union:________________Village:________________
Age: __________Sex:__________Occupation: ________________________________

	Age	Education Level	Sex	Occupation	Number of Adult in Family	Total Monthly Income
1						
2						
3						
4						
5						
6						

1. Please indicate the amount of land you (lease out, own, lease from owners) by circling the number representing the amount of land in hectares.

   1 2 3 4 5

2. How long have u been living in this village? __________________ Years.

3. What problems are you facing in this village?

   ____
   ____
   ____

4. What is the main source of water and how long have you been using it?

   1) Tubewell: _______ years 3) River: _______ years
   2) Pond: _______ years 4) Deep tubewell: _______ years

5. What is your knowledge of arsenic poisoning and its health hazards:

   1) No threat
   2) Slight threat
   3) Moderate threat
   4) High threat
   5) Very high threat

6. Do you have radio or television in your house (circle one)? Yes No

   If you answered yes, what do you have?

   1) Radio
   2) Television
   3) Newspaper
   4) Cable Network
   5) Computer (internet)

7 From whom did you hear about arsenic?

   1) Village doctor
   2) Educated neighbor
   3) Local commissioner's office
   4) Government health workers
   5) NGO workers

8. Did you read any written materials about arsenic (circle one)? Yes No

   If yes, what did you read?

   1) Pamphlets
   2) Books
   3) Newspaper
   4) Posters

9. How long have you known about the potential health hazards related to arsenic poisoning (Please circle the numerical value indicating the numbers of years).

   1 2 3 4 5

10. How do you think arsenic might enter into your body?

    1) Have no idea
    2) Using/drinking pond water
    3) Using/drinking dug well water
    4) Use of chemical/fertilizers
    5) Using/drinking tube well water

11. Did you test your water for arsenic contamination (circle one)? Yes No

    If yes, how long ago did you conduct the testing (numerical values indicates number of years).

    1 2 3 4 5

12. If your water is contaminated, do you still use it for drinking and cooking purposes? Yes No

    If yes, for long are you using the water (numerical values indicates number of years)

    1 2 3 4 5

13. If no, then what is your alternate source for the water?

    1) Other tube-wells
    2) Neighboring villages
    3) Pond or river
    4) Bottle water / government supplied water

14. Who tested your water for arsenic contamination?

    1) Health workers
    2) NGO workers
    3) University/governmental research institutes
    4) Foreign research agencies

15. How far do you go to collect your water (numerical values indicates hundreds of feets)

    1 2 3 4 5

Please answer 17-19 if you answer yes to the following question. Otherwise, go to question 20.

16. Do you have any patients in your family (circle one)? Yes No

    If yes, then who and what is their approximate age?

    1) Father/mother: _______ years
    2) Son/daughter: _______ years
    3) Brother/sister: _______ years
    4) Husband/wife/self: _______ years
    5) Neighbor/friend: _______ years

17. Which of the following do you think are symptoms of arsenic poisoning?

    1) Irritation in gastro-intestinal and upper respiratory tracts
    2) Light skin pigmentation
    3) Keratoses
    4) Skin, lungs, and pancreatic cancer

18. How long has he/she been suffering (numerical values indicate numbers of years)?

    1 2 3 4 5

19. What type of medications may he/she be using?

    1) No medications currently used
    2) Homeopathy medications
    3) Herbal medications
    4) Allopathic medications
    5) Others (please indicate): ______________________________

20. Do you know of any mitigation processes available in your village (please circle one)?

    Yes No

    If yes, who is presenting/evaluating the available option?

    1) Bangladesh government
    2) University research groups
    3) Non-governmental agencies
    4) Village development agencies

21. Are you involved in any groups mentioned in the previous question (please circle one)?

Yes No

If yes, please circle one

1) Bangladesh government
2) University research groups
3) Non-governmental agencies
4) Village development agencies

22. Which of the following do you believe is a viable mitigation option for treating arsenic contaminated drinking water?

1) Deep tube well water
2) Rain water
3) Three bucket filtration system

23. How would you perceive the benefits of the mitigation process?

1) No benefits
2) Slightly beneficial
3) Fairly beneficial
4) Moderately beneficial
5) Extremely beneficial

24. Do you have confidence in the government or NGO workers in combating arsenic contamination?

1) No idea
2) Not very confident
3) Fairly confident
4) Moderately confident
5) Extremely confident

25. Are you interested in participating in group arsenic mitigation activities?

1) Not willing at all
2) Slightly willing to participate
3) Moderately willing to participate
4) Willing to participate
5) Very willing to participate

26. How would you participate if you?

    1) Helping with research organizations
    2) Sponsoring projects
    3) Contributing money
    4) Carry water from arsenic free tube wells to neighborhoods

27. How much are you willing to contribute towards arsenic mitigation?

    1) Up to Taka 100
    2) Up to Taka 200
    3) Up to Taka 300
    4) Up to Taka 400

28. Do you feel you know enough about arsenic (please circle one)?

    Yes No

    If you answered no, would you like to know more (please circle one)?

    Yes No

Name of person conducting the interview: ______________________________

Date: ______________________________

APPENDIX II

HUMAN PERCEPTION SCORES AND INDIVIDUAL PARTICIPATION SCORES FOR ALL THREE VILLAGES

Village	S	W	T	H	HPS	HPS (Z)	M	E	N	DO	IPS	IPS (Z)
Bakaborshi	5	5	5	4	19 00	1 14553	4	5	4	3	16 00	1 17504
Bakaborshi	5	4	5	2	16 00	03744	4	3	1	3	11 00	-1 01521
Bakaborshi	5	5	5	1	16 00	.03744	4	2	2	4	12 00	- 57716
Bakaborshi	5	5	5	2	17 00	40680	1	2	4	3	10 00	-1 45326
Bakaborshi	5	4	5	1	15 00	- 33193	4	2	2	2	10 00	-1 45326
Bakaborshi	5	5	5	1	16 00	03744	4	2	2	2	10 00	-1 45326
Bakaborshi	1	2	2	2	7 00	-3 28684	3	1	1	2	7 00	-2 76741
Bakaborshi	4	4	5	2	15 00	- 33193	4	3	3	3	13 00	- 13911
Bakaborshi	5	4	5	3	17 00	40680	4	4	3	5	16 00	1 17504
Bakaborshi	1	2	3	3	9 00	-3 28684	1	1	1	5	8 00	-2 32936
Bakaborshi	2	2	3	1	8 00	-4 02556	1	2	3	4	10 00	-1 45326
Bakaborshi	4	4	5	2	15 00	- 33193	4	4	3	3	14 00	29894
Bakaborshi	5	4	5	2	16 00	03744	4	2	3	3	12 00	- 57716
Bakaborshi	5	5	5	1	16 00	03744	4	2	1	5	12 00	- 57716
Bakaborshi	5	3	5	1	14 00	- 70129	5	2	2	1	10 00	-1 45326
Bakaborshi	5	3	5	1	14 00	- 70129	4	2	2	3	11 00	-1 01521
Bakaborshi	5	4	5	1	15 00	- 33193	4	3	2	3	12 00	- 57716
Bakaborshi	5	5	5	3	18 00	77616	4	3	2	3	12 00	- 57716
Bakaborshi	5	5	5	3	18 00	77616	4	3	4	5	16 00	1 17504
Bakaborshi	4	3	5	3	15 00	- 33193	4	2	3	2	11 00	-1 01521
Bakaborshi	5	5	5	3	18 00	77616	4	3	3	4	14 00	29894
Bakaborshi	5	5	5	2	17 00	40680	5	4	5	3	17 00	1 61309
Bakaborshi	4	4	5	2	15 00	- 33193	5	3	5	3	16.00	1.17504
Bakaborshi	4	4	5	4	17 00	40680	5	4	4	3	16 00	1 17504
Bakaborshi	4	2	5	1	12 00	-1 44002	5	2	2	3	12 00	- 57716
Bakaborshi	4	5	5	4	18 00	77616	5	3	3	4	15 00	.73699
Bakaborshi	4	4	5	3	16 00	03744	4	1	2	1	8 00	-2 32936
Bakaborshi	5	5	5	4	19 00	1 14553	5	4	4	2	15 00	73699
Bakaborshi	4	4	5	2	15 00	- 33193	4	3	2	3	12 00	- 57716
Bakaborshi	5	5	5	5	20 00	1 51489	5	4	4	4	17 00	1 61309
Bakaborshi	5	5	5	3	18 00	77616	4	4	2	5	15 00	73699
Bakaborshi	5	5	5	3	18 00	77616	3	4	2	3	12 00	- 57716
Bakaborshi	4	4	4	3	15 00	- 33193	5	4	1	4	14 00	29894
Bakaborshi	4	4	4	4	16 00	03744	4	3	2	4	13 00	- 13911
Bakaborshi	4	4	4	4	16 00	03744	4	4	2	4	14 00	29894
Bakaborshi	4	4	4	3	15 00	- 33193	4	4	2	4	14 00	.29894
Bakaborshi	4	4	5	5	18 00	77616	4	4	1	3	12 00	- 57716
Bakaborshi	4	5	5	3	17.00	.40680	5	4	2	3	14.00	.29894
Bakaborshi	4	5	5	3	17 00	40680	5	4	2	3	14 00	29894
Bakaborshi	3	4	4	4	15 00	- 33193	4	4	3	5	16 00	1 17504
Bakaborshi	5	4	5	3	17 00	40680	4	5	5	2	16 00	1.17504
Bakaborshi	3	4	5	3	15 00	- 33193	4	4	2	4	14 00	.29894
Bakaborshi	3	5	4	1	13 00	-1 07066	3	2	2	3	10 00	-1 45326
Bakaborshi	5	4	5	3	17 00	40680	5	2	2	3	12 00	-.57716

Village	S	W	T	H	HPS	HPS (Z)	M	E	N	DO	IPS	IPS (Z)
Bakaborshi	5	5	5	5	20 00	1 51489	4	3	2	3	12 00	- 57716
Bakaborshi	5	5	5	3	18 00	77616	5	2	2	3	12 00	-.57716
Bakaborshi	5	4	5	5	19 00	1 14553	4	4	3	4	15 00	73699
Bakaborshi	5	4	5	2	16 00	03744	4	2	2	1	9 00	-1 89131
Bakaborshi	4	4	5	5	18 00	77616	5	5	5	2	17 00	1 61309
Bakaborshi	4	3	5	5	17 00	40680	4	3	3	3	13 00	-.13911
Rajarampur	5	4	5	1	15 00	- 33193	3	4	2	4	13 00	- 13911
Rajarampur	5	4	5	3	17 00	40680	3	3	2	5	13 00	- 13911
Rajarampur	5	4	5	4	18 00	77616	5	3	4	4	16 00	1 17504
Rajarampur	5	4	5	3	17 00	40680	5	5	5	4	19 00	2.48919
Rajarampur	5	4	5	3	17 00	40680	4	2	4	4	14 00	29894
Rajarampur	5	3	5	5	18 00	77616	3	3	5	4	15 00	73699
Rajarampur	4	4	3	3	14 00	- 70129	4	3	3	4	14 00	29894
Rajarampur	4	4	5	4	17 00	.40680	5	4	3	2	14 00	29894
Rajarampur	4	4	3	3	14 00	- 70129	4	4	2	3	13 00	- 13911
Rajarampur	4	4	3	2	13 00	-1 07066	4	3	2	4	13 00	- 13911
Rajarampur	5	5	5	1	16 00	03744	4	3	3	3	13 00	- 13911
Rajarampur	4	4	5	4	17 00	40680	4	3	2	4	13 00	- 13911
Rajarampur	4	4	4	4	16 00	03744	5	4	2	4	15 00	73699
Rajarampur	4	5	5	4	18 00	77616	5	4	3	4	16 00	1.17504
Rajarampur	4	4	3	4	15 00	- 33193	5	3	3	4	15 00	.73699
Rajarampur	5	5	5	4	19 00	1 14553	3	5	4	4	16 00	1 17504
Rajarampur	4	1	5	4	14 00	- 70129	4	4	4	3	15 00	73699
Rajarampur	4	4	5	3	16 00	03744	5	4	2	3	14 00	29894
Rajarampur	1	2	5	3	11 00	-1 80938	3	5	4	3	15 00	73699
Rajarampur	3	2	5	3	13 00	-1 07066	5	4	1	3	13 00	- 13911
Rajarampur	4	4	5	4	17 00	40680	4	4	2	4	14 00	29894
Rajarampur	4	4	5	4	17.00	40680	4	4	2	1	11 00	-1 01521
Rajarampur	4	4	5	3	16 00	03744	5	5	2	2	14 00	.29894
Rajarampur	5	5	5	3	18 00	77616	5	4	2	3	14 00	.29894
Rajarampur	3	4	3	5	15 00	- 33193	5	4	2	4	15 00	73699
Rajarampur	4	4	5	3	16 00	03744	4	3	2	3	12 00	- 57716
Rajarampur	4	4	5	4	17 00	40680	3	4	4	4	15 00	73699
Rajarampur	5	5	5	3	18 00	77616	5	3	2	4	14 00	29894
Rajarampur	5	5	5	2	17 00	40680	4	4	2	4	14 00	29894
Rajarampur	4	4	5	2	15 00	- 33193	4	2	2	4	12 00	- 57716
Rajarampur	5	5	5	2	17 00	40680	4	2	2	1	9 00	-1 89131
Rajarampur	5	5	5	3	18 00	77616	5	5	5	2	17 00	1 61309
Rajarampur	5	5	5	5	20 00	1 51489	4	4	2	3	13 00	- 13911
Rajarampur	4	5	5	5	19 00	1 14553	3	3	3	4	13 00	-.13911
Rajarampur	4	3	5	3	15 00	- 33193	4	2	2	3	11 00	-1 01521
Rajarampur	4	4	5	2	15 00	- 33193	3	2	2	4	11 00	-1.01521
Rajarampur	4	4	5	2	15 00	- 33193	4	4	2	4	14 00	29894
Rajarampur	5	5	5	3	18 00	77616	4	3	3	3	13 00	- 13911
Rajarampur	5	4	5	5	19 00	1 14553	3	4	4	3	14 00	29894
Rajarampur	1	2	1	4	8 00	-2 91747	3	3	3	3	12 00	- 57716
Rajarampur	4	4	5	2	15.00	- 33193	5	2	2	3	12 00	- 57716
Rajarampur	1	4	1	1	7 00	-3 28684	1	3	1	2	7 00	-2 76741
Rajarampur	2	2	5	1	10 00	-2 17875	4	4	2	1	11 00	-1 01521
Rajarampur	5	5	5	4	19 00	1 14553	5	3	4	2	14 00	29894
Rajarampur	2	2	5	3	12 00	-1 44002	3	4	1	3	11 00	-1 01521
Rajarampur	2	2	5	2	11 00	-1 80938	3	3	1	4	11.00	-1 01521
Rajarampur	5	3	5	2	15 00	- 33193	4	5	3	3	15.00	.73699
Rajarampur	1	2	1	5	9 00	-2 54811	2	4	4	4	14 00	29894
Rajarampur	5	4	5	5	19 00	1 14553	4	2	4	3	13 00	-.13911
Rajarampur	5	5	5	5	20 00	1 51489	5	4	4	3	16 00	1.17504
Samta	5	3	5	2	15 00	- 33193	5	5	4	3	17 00	1.61309
Samta	5	5	5	3	18 00	77616	4	4	4	3	15 00	.73699

Village	S	W	T	H	HPS	HPS (Z)	M	E	N	DO	IPS	IPS (Z)
Samta	5	4	5	3	17 00	40680	4	2	4	4	14 00	29894
Samta	5	5	5	5	20 00	1 51489	4	4	4	2	14 00	29894
Samta	4	4	5	4	17 00	40680	4	3	1	2	10 00	-1 45326
Samta	4	5	5	3	17 00	40680	4	4	4	3	15 00	73699
Samta	2	2	5	3	12 00	-1 44002	4	4	1	3	12 00	- 57716
Samta	3	4	5	3	15 00	- 33193	4	2	1	4	11 00	-1 01521
Samta	2	2	5	4	13 00	-1 07066	4	2	1	4	11 00	-1 01521
Samta	4	5	5	2	16 00	03744	4	3	1	3	11 00	-1 01521
Samta	2	1	5	3	11 00	-1 80938	3	2	1	3	9 00	-1 89131
Samta	3	3	5	3	14 00	- 70129	4	2	2	3	11 00	-1 01521
Samta	3	2	5	4	14 00	- 70129	5	4	1	1	11 00	-1 01521
Samta	3	2	5	4	14 00	- 70129	3	3	2	3	11 00	-1 01521
Samta	5	4	5	3	17 00	40680	4	5	4	3	16 00	1 17504
Samta	2	1	5	3	11 00	-1 80938	4	4	4	3	15 00	73699
Samta	5	4	5	3	17 00	40680	4	2	2	3	11 00	-1 01521
Samta	3	4	5	2	14 00	- 70129	4	4	1	2	11 00	-1 01521
Samta	2	3	5	3	13 00	-1 07066	3	5	4	4	16 00	1 17504
Samta	5	4	5	3	17 00	40680	4	4	4	3	15 00	73699
Samta	5	5	5	3	18 00	77616	4	5	4	3	16 00	1 17504
Samta	5	5	5	5	20 00	1 51489	5	2	4	3	14 00	29894
Samta	5	1	5	3	14 00	- 70129	5	2	3	3	13 00	- 13911
Samta	3	5	5	3	16 00	03744	4	4	1	4	13 00	- 13911
Samta	5	4	5	3	17 00	40680	4	2	1	1	8 00	-2 32936
Samta	5	4	5	5	19 00	1 14553	5	4	4	2	15 00	73699
Samta	4	5	5	3	17 00	40680	4	2	2	3	11 00	-1 01521
Samta	4	5	5	4	18 00	77616	5	3	3	4	15 00	73699
Samta	5	4	5	4	18 00	77616	4	4	4	4	16 00	1 17504
Samta	3	4	5	4	16 00	03744	4	4	3	3	14 00	29894
Samta	5	4	5	3	17 00	40680	5	4	2	4	15 00	73699
Samta	5	5	5	3	18 00	77616	5	3	2	4	14 00	29894
Samta	4	4	5	3	16 00	03744	4	4	2	4	14 00	29894
Samta	5	4	5	4	18 00	77616	4	4	2	4	14 00	29894
Samta	5	5	5	3	18 00	77616	4	4	2	2	12 00	- 57716
Samta	4	4	5	4	17 00	40680	5	3	4	4	16 00	1 17504
Samta	5	4	5	3	17 00	40680	5	5	4	4	18 00	2 05114
Samta	5	3	5	3	16 00	03744	4	4	1	4	13 00	- 13911
Samta	3	4	5	4	16 00	03744	4	4	2	4	14 00	29894
Samta	3	4	5	3	15 00	- 33193	5	4	2	2	13 00	- 13911
Samta	4	4	5	3	16 00	03744	4	4	2	3	13 00	- 13911
Samta	4	5	5	3	17 00	40680	3	5	4	4	16 00	1 17504
Samta	2	4	5	5	16 00	03744	4	4	5	3	16 00	1 17504
Samta	5	4	5	4	18 00	77616	4	3	4	4	15 00	73699
Samta	5	4	5	3	17 00	40680	5	4	2	4	15 00	73699
Samta	5	5	5	3	18 00	77616	3	3	4	4	14 00	29894
Samta	5	4	5	3	17 00	40680	4	4	5	4	17 00	1 61309
Samta	4	5	5	2	16 00	03744	5	2	2	4	13 00	- 13911

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VITA

Muhammad Tauhidur Rahman was born in Meherpur, Bangladesh, on December 19, 1979, the son of Abu Muhammad Shajaat Ali and Mashkura Shajaat Ali. After completing his studies at Chapel Hill High School in Tyler, Texas, during June of 1997, he entered The University of Texas at Austin in August of 1997. He graduated with a Bachelor of Arts (with departmental honors) degree in Geography in May of 2002. In August of the same year, he entered the Graduate School of Texas State University-San Marcos, Texas to pursue a Master of Science degree in Geography.

Permanent Address: 3400 Varsity Drive, #2508
Tyler, TX 75701.

This thesis was typed by Muhammad Tauhidur Rahman.