Arsenic Contamination in Groundwater and Foods and Its Psychosocial Effects on Rural Bangladeshi Children

バングラデシュ農村部における地下水・食物の
砒素汚染とそれが子供に及ぼす心理社会的影響

A Thesis

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Mst. Nasrin Nahar

Abstract

Exposure to arsenic through drinking water sourced from groundwater is a global public health problem, which is particularly devastating in Bangladesh. Chronic exposure to arsenic (over 10 years) is reported to cause specific skin lesions such as melanosis, keratosis, or gangrene as well as non-specific health problems like hypertension, anemia, and even affect the peripheral and central nervous system. Besides these health effects, arsenic patients in Bangladesh suffer not only from economic burden of medical costs but also from psychological suppression and social discrimination, therefore, it is necessary to pay special attention to the children because they are still growing and developing mentally and socially, and thus they may show possible chronic effects. Very few studies have been conducted on As exposure and children's psycho-social development like intellectual function, e.g., IQ (Intelligence Quotient) and social competence (SC).

The present study aimed to clarify the effect of As exposure on IQ and SC of 720 children from Sonargaon thana located approximately 40 km southeast of Dhaka. The study subjects were divided into three age groups i.e. 4-5 years, 9-10 years and 14-15 years to (1) evaluate the relationship between As exposure (urinary As concentration) and IQ as well as SC and to (2) evaluate at what developmental stage the effect of As starts. Thereafter, in order to evaluate the contribution of sources other than drinking water to As exposure, the amount of water used during cooking of the most frequently consumed food according to the FFQ (rice) was measured. IQ was assessed by Raven's standard progressive matrices (9 & 10 year and 14 & 15 year groups) and Kaufman Brief Intelligence Test (4 & 5 year group), and for measuring SC, the Bengali version of Texas Social Behavior Inventory (TSBI) Form-A was

employed（over 9 & 10 year groups）. In addition, the As concentration in the staple food, rice, was also measured.

From the findings, (1) As exposure was higher in children from low income families, even after controlling for factors like household income and parental education level, As exposure was negatively correlated with IQ in all three age groups. (2) Regarding IQ, the effect of As exposure was seen from 4 years old. (3) The FFQ survey results revealed that rice was consumed the most frequently (more than once daily), followed by daal (bean) soup and finally non-leafy vegetables (almost once a day), but fish, meat and eggs were consumed approximately once a week. Water intake per meal from cooked rice was estimated to be 629 ml/person, followed by daal soup (278 ml/person), and cooked vegetables (88 ml/person). Our results suggest that the water used for cooking might be an important source of As.

In conclusion, even though the children from low income families know that their tubewells are contaminated with high levels of As, they are in no position to use alternative methods like changing tubewells or buying filters so they continue consuming As contaminated water. This could be one of the reasons as to why the psycho-social effects of As exposure start from early developmental stages. In addition, the possibility of As entering into the body through the irrigation and cooking water is high even if considering the high concentration of As in drinking water in the highly contaminated areas. In order to minimize the aforementioned effects of As exposure, there is need for urgent interventions.

概要

飲料水としての地下水をとおした砒素暴露の問題は大きな公衆衛生問題であり、特にバングラデッシュでは顕著である。例えば長期間（10 年以上）の砒素摂取により、メラノシス・角化症・壊疽などの皮膚障害の他、高血圧・貧血・末梢神経や中枢神経障害などの健康問題を引き起こすことが報告されている。また、これらの健康問題をかかえた砒素患者は、医療費の経済的負担ばかりでなく精神的抑圧や社会的差別を受けることにもなる。特に、精神的にも社会的にも発達途上の子供たちにとっては砒素による社会心理的な影響はより深刻な問題である。しかしながら、砒素暴露と子供の発達や社会心理の関連に関する研究はほとんど行われていない。そこで本研究は、子供の知能（IQ: Intelligence Quotient）及び社会的能力（SC: Social Competence）の調査を通して、砒素暴露が子供に与える社会心理的上の影響について考察することを目的としている。

研究は、首都ダッカの南 40ｋｍに位置する農村、ショナルゴン地域の子供 720 人を対象とし、①4～５歳、９～10 歳、14～15 歳の３つの年齢層に分けて砒素暴露（尿中の砒素濃度）とIQ、SCとの関連について検討するとともに、②砒素の影響が発達段階のいつから顕在化するかを検討した。次に、飲水以外の経口砒素暴露を検討するため、③摂取頻度の高かった食物（料理）について調理中に使われる水の量の測定を行った。

IQの測定は 9～10 才と 14～15 才のグループは Raven's standard progressive matrices、4～5 才はKaufman Brief Intelligence を用いた。SCは測定可能な 9～10 歳、14～15 歳にのみ、 the Bengali version of Texas Social Behavior Inventory From-A を使用して測定した。また、主食である米については米そのものに含まれる砒素量も測定した。

その結果、①砒素暴露量は家庭の収入が低い子供ほど高いこと、砒素暴露量は家庭の収入や親の学歴などをコントロールしてもすべての年齢層（SCのみ 9 歳以上）においてIQやSCと有意な負の関係を示すこと、②IQ については、4 歳から社会心理に影響があることが明らかとなった。また、③FFQ調査より特に摂取頻度が高いことがわかった料理（3 品目）から摂取される砒素量は、米（629ml/人/日）、豆スープ（278ml）、根菜料理（88ml）であり、特に主食である米を通した砒素摂取量が大きいことが明らかになった。

以上の結果からは、低収入の家庭の子供は、危険な量の砒素が含まれていると知っていても、回避するための手段（井戸の場所を変えたりフィルターを購入したりすること）が取れないために日常生活の中でその井戸水を利用せざるを得ないこと、そのことによって発達の早い段階から社会心理的な影響を受けていることが推察できる。また、ヒ素汚染地域では飲料水に配慮していても、料理用の水や、灌漑用水を通してヒ素が体内にとりこまれる可能性も高い。このようなリスクを回避する方法を早急に考える必要がある。

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Chapter I

Introduction

1.1 Arsenic contamination in groundwater of Bangladesh

Arsenic (As) is a metalloid, naturally and anthropogenically occurs in the environment (Smedley and Kinniburgh, 2002), and widely distributed in air, water, soils, plants and animals in variable concentrations. Throughout the history As is known as carcinogen to human (Centeno *et al.*, 2002; Cullen, 2008). Later, a number of landmark epidemiological studies (for example: Tseng *et al.*, 1968; Chen *et al.*, 1988) have highlighted the susceptibility of the population to develop cancer due to chronic As exposure through drinking water and established the dose-response relationship between As concentration and As toxicity (Hughes *et al.*, 2011). Consequently, in 1992, World Health Organization (WHO) decreased the provisional drinking water guideline for As from 50 μg L^{-1} to 10 μg L^{-1} (WHO, 1993). The exposure (ingestion, inhalation and dermal) to As may cause both non-carcinogenic and carcinogenic health effect to human body (Kapaj *et al.*, 2006). The extent of toxicity vary among individuals depending on the rate of ingestion, duration of exposure and methylation capacity of individuals determined by cofactors such as genetic factor, gender, age, ongoing medication, nutritional status, smoking habit and intake of alcohol, coffee and tea (Tseng, 2009). The most common health outcomes are development of hypertension, diabetics and cardio vascular diseases; neurobehavioral change in adolescence and neuropathic effects; diminished IQ and long-term memory loss; abnormal pregnancy outcomes among women; development of skin lessons (e.g. melanosis, leucomelanosis, keratosis, hyperkeratosis hyperkeratosis etc.); incidence of cancer in gastrointestinal, liver and respiratory tract etc. (Bates *et al.*, 1992; Hopenhayn-Rich *et al.*, 2000; Vahter and Concha, 2001; Kapaj *et al.*, 2006; Smith and Steinmaus, 2009; Chatterjee *et al.*, 2010; Hughes *et al.*, 2011). Over the last few decades, the contamination of drinking water and groundwater by As has been highlighted as an environmental disaster in many regions of the world, including in the countries of Europe, North America and Australia (Nordstrom, 2002; Nriagu *et al.*, 2007), and has been reported from over 70 countries a serious health hazard to an estimated 150 million people world-wide (Ravenscroft *et al.*, 2009). The global map indicating the arsenic contaminated countries is shown in Fig. 1.1. The problem is most acute in South and Southeast Asia, particularly in eastern to northeastern part of India and adjoining Bangladesh, jointly called Bengal Basin (Chakraborti *et al.*, 2004, 2008; Bhattacharya *et al.*, 2011). More than 80 percent people in the world are exposed to high levels of As in groundwater live in Asia (UNICEF on 5th April, 2009). In early of 1970s people living in this region were compelled to shift their drinking water source from surface water to groundwater to avoid various water borne diseases like diarrhea and cholera (Mukherjee *et al.*, 2007). Millions of hand pumped tubewells were installed mostly by private initiatives in the shallow aquifers (< 50 m) (Escamilla *et al.*, 2011). At present, about 95% people living in this region are heavily dependent on groundwater for domestic purposes like drinking, cooking, bathing and washing (Chatterjee *et al.*, 2010; Fendorf *et al.*, 2010). Consequently, the occurrences of high As in shallow groundwater has caused severe mass poisoning putting millions people at risk in this region (Smith *et al.*, 2000; Chakraborti *et al.*, 2004, 2008, 2010; Chatterjee *et al.*, 2010).

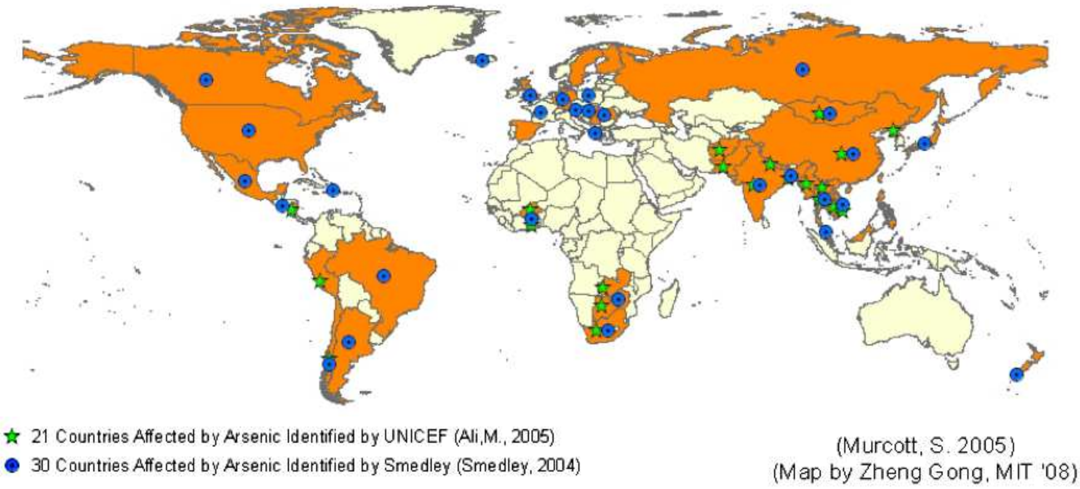
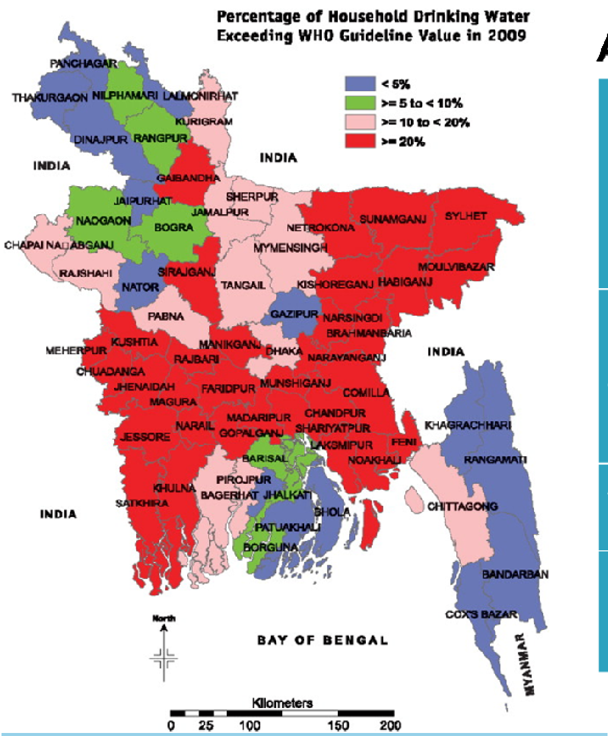


Figure 1.1 The global map of arsenic contamination

Bangladesh is grappling with the largest mass poisoning of a population in the human history because groundwater used for drinking has been contaminated with naturally occurring inorganic As (Smith *et al*., 2000). It is estimated that of the 160 million inhabitants of Bangladesh around 80 million in 61 of 64 districts are at risk of drinking As contaminated groundwater, and about 35 million people are taking As contaminated groundwater exceeding the national safety level (50 μg L^{-1}) of Bangladesh. The As contamination in groundwater is the largest scale poisoning in the physical environment of the human community ever experienced in the territory. The As contamination in groundwater is a naturally occurring geological deposit in Bangladesh. The alluvial soil of Bangladesh consists of deposits of volcanic emission and gradually eroded rocks with arseno pyrite, and pyrite carried by rivers from Himalayas. It believed that the As has been in the groundwater for many years before the recent extensive withdrawal of groundwater. In 1993, Bangladesh detected As in four tube wells at the northern borderline village Chamagram under Barogharia union of Chapainawabgonj district. Although in 1993 the number of As-affected district in Bangladesh was one, it rose to 61 in the year 2000. Figure 1.2 shows the map of As contaminated areas in Bangladesh. Ninety seven percent of people in Bangladesh use tubewell water for drinking and other purposes from about 8.6 million hand tubewells (HTWs). Contaminated tube wells act as reservoirs of liquid poison, As. High concentrations of naturally occurring As in drinking water supplied by approximately 1.4 million tube wells (UNICEF, October 2008). It has been estimated that 27% of shallow tubewells that is, wells not deeper than 50 meters exceeded Bangladesh's guideline value of As and 46% of these tubewells exceeded WHO's guideline value. As concentration might vary considerably from well to well in the same area and even in the same well water at different time.



Source: Bangladesh Bureau of Statistics and UNICEF, 2009

As situation in Bangladesh

Population at risk (Out of 160 million)	77 million (> 10 ppb) 20 million (> 50 ppb)
No. of tube well contaminated (Out of 8.6 million)	1.4 million (> 50 ppb)
As range	0– 3,000 ppb
No. of district affected	61 (out of 64)

Source: UNICEF, 2010

Figure 1.2 The map of arsenic contaminated areas in Bangladesh

Intermittent incidents of As contamination in groundwater can arise both naturally and industrially. The natural occurrence of As in groundwater is directly related to the As complexes present in soils as mentioned earlier. As can liberate from these complexes under some circumstances. Since As in soils is highly mobile, once it is liberated, it results in possible groundwater contamination. The effect of As is associated with its type (inorganic As is more toxic than organic As), chemical form (trivalent As is more toxic than pentavalent As), route of entry (ingestion), doses and duration of exposure, age, sex, education and nutritional status (malnutrition is contributory) and body defense mechanism of the affected people. Chronic exposure to As at concentration greater than 0.05mgL^{-1} or 50ppb cause health problem ranging from morbidity to effect on the peripheral and central nervous system, etc. Some pictures of As effects on physical health in Bangladesh are shown in the Fig. 1.3.

Keratosis Sole | Melanosis on Hand | Gangrene

Figure 1.3 Physiological effects of arsenic

1.2 Main pathways of arsenic into the human body

Arsenic, a toxicant of natural occurrence in mineral deposits, is used in many human activities such as manufacturing, agriculture, and medicine (WHO, 1981). Arsenical compounds are transported into the environment mainly by water from wells drilled into the arsenic-rich geologic strata or by ambient air during smelting and burning of coal (WHO, 1981; Thornton and Farago, 1997). The main route of As exposure for the general population is via drinking water. Arsenite and arsenate are the most common forms of As in groundwater, as well as the most toxic of the four compounds. The pathway they follow through the human body is incredibly important to understanding arsenicosis, the disease caused by chronic As poisoning. Generally, there are two main ways in which As poses a health threat to humans: ingestion and inhalation. Figure 1.4 shows main pathways of arsenic from different sources into the human body through ingestion. As is not readily absorbed through skin so physical contact with contaminated water, for bathing and washing, is not toxic (BBS and UNICEF, 2010). Around 95% of As enters to human body by ingestion. Ingested As can enter into two ways: directly and indirectly. Arsenic from groundwater can enters into human body by contaminated drinking water and cooking water. It also enters to human body by using contaminated water in irrigation and then it come to the soil to grain or vegetables and finally to human body. From soil it also enters to human body through live stoke indirectly.

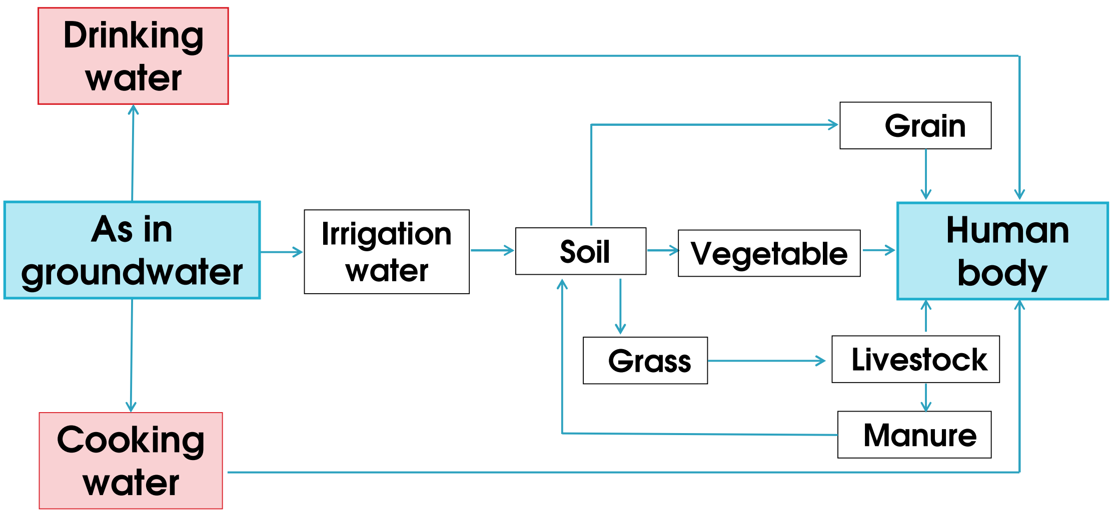


Figure 1.4 Main pathways of arsenic into the human body

When arsenite and arsenate enter the human body, they bind to tissues, inhibit enzyme activity, and interfere with cell respiration and mitosis. In order to reduce the detrimental effects of these compounds, the body uses a detoxifying methylation mechanism to convert arsenite and arsenate to inorganic MMA and DMA. However, during the conversion of inorganic species to organic species, an extremely toxic intermediary compound, MMA is formed. Many scientists are currently studying this compound since it may add significantly to the overall carcinogenicity of inorganic As. Once inorganic forms have been converted to MMA and DMA, they are excreted from the body. Thus, the presence of DMA and MMA in the urine, skin, hair, and nails are often evidence of As poisoning. Urinary As content best indicates recent exposure to As, since As appears in the urine within two to eight hours and disappears within seven days. As content in the skin, hair and nails is more useful for measuring long-term exposure to As.

1.3 Socio-economic condition and arsenic contamination

Bangladesh is one of the least developed countries in the world with about 140 million people in an area of 147 thousand sq. km and with an annual per capita income of $418 (2003-04). In 2004, 43.6% of the urban and 40.1% of the rural people were surviving under the poverty line I (Absolute Poverty), and 20.8% of the urban and 18.2% of the rural people under the poverty line II, called the ‘Hardcore Poverty’. Poverty is overwhelming in Bangladesh. It is deep rooted in economic, political and social processes and is the outcome of multidimensional factors. Although declining by 1% annually in the 1990s, the incidence of poverty at national level continues to be high at about 50% in 2000.

There is a strong link between poverty and As, such as arsenicosis enhances the economic burden of the poor. The majority of victims are considered as a burden to their family and society. Most of the poor arsenicosis patients remain untreated due to financial restraints. For example, 20-70% of the patients did not receive any treatment in Bangladesh due to financial problems, and mostly rural people could not take any step to take As free water also due to their financial problem. This lack of treatment further deteriorates the overall health and economic conditions of arsenicosis victims. Because poverty rises as the untreated poor victims are incapable of doing hard work and gradually lose strength to move. This disease is associated with social discriminations such as losing jobs, barriers to access new jobs and social rejections. Again, if the poor arsenicosis patients go for treatment, they need to spend a big proportion of their money on this, which finally diminishes the household income and increases the economic burden on the poor victims and their families. Moreover, the cost of obtaning As free water also diminishes household income (Alistair *et al.*, 2000)

Higher income households might have greater storage facilities for their tubewell water and might consequently be able to store the water for longer. In Bangladesh it is likely that access to tubewell drinking water at least partially determined by social status, and the social status is defined by their household income also. Therefore, there could be a relationship between As exposure in drinking water and socio-economic status.

1.4 Psychosocial effects by arsenic exposure

Besides the physical health effects that mentioned in the earlier section, As exposure has some psychological effects (e.g. reduction in intelligence and social competence) as well as has some social effects.

<u>Intelligence quotient (IQ)</u>

Human intelligence, mental quality that consists of the abilities to learn from experience, adapt to new situations, understand and handle abstract concepts, and use knowledge to manipulate one's environment. Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought (Ulrich *et al.*, 1996). In other words, intelligence is part of the internal environment that shows through at the interface between person and external environment as a function of cognitive task demands (Sattler, 2001).

***Factors influencing the intelligence*:** Psychologists have spent a great amount of time and energy debating the various influences on individual intelligence. Today, nearly all psychologists recognize that there seem to be three main factors play a role in determining intelligence. It now becomes matter of determining exactly how much of an influence each factor has.

1. Brain: The brains of very intelligent children appear to develop in a distinctive and surprising way that distinguishes them from less intelligent children. The study by the National Institute of Mental Health who did several brain scans on 309 healthy children between the ages of 6 and 19 is the first to try to measure whether differences in brain development are linked to intelligence. The scans showed that children with the highest IQs began with a relatively thin cortex - the folded outer layer of the brain that is involved in complex thinking.

2. Genetics: First, it is important to note that genetics and environment interact to determine exactly how inherited genes are expressed. For example, if a person has tall parents, it is likely that the individual will also grow to be tall.

However, the exact height the person reaches can be influenced by environmental factors such as nutrition and disease. Some evidence of genetic influences is given below:

A twin studies suggest that identical twins IQ's are more similar than those of fraternal twins (Promin & Spinath, 2004). Siblings reared together in the same home have IQ's that are more similar than those of adopted children raised together in the same environment (McGue & others, 1993).

3. Biology and Biochemistry: There are a wide range of biological factors that can impact intelligence, cognitive ability, and neurological functioning. Four are listed below. Of note, the correlations are small or unclear in many studies, as researchers often try to find an effect very early in life or to isolate all possible confounding factors:

Prematurity: associated with a host of medical complications (like respiratory problems, asphyxia, and apnea), visual-motor coordination problems, MR, and LD.

Drug exposure: often leads to poorer organizational and language skills, even if the children are in the lower end of the average range.

Exposure to toxins: like lead from lead paint, lead soldered pipes, As from ground water and pollution is associated with long-term low achievement, cognitive deficits, and neurological impairment.

Aging: would be a fourth factor that comes under the biology heading

- studies show a clear decline in tested skills in the elderly in labs, but typically no corresponding decrement in daily functioning

- older adults can practice test taking skills and cognitive problem-solving skills (metacognition) and improve IQ scores, raising the question of whether aging or disuse caused their skills to decline
- older adults can "upgrade" their skills by learning new things to do, new strategies to do them, and new ways to monitor their success (executive functioning)

4. Environment: There are a number of environmental factors that impact child cognitive development:

   Demographics - this relates to statistically likely experiences based on what we know about the biological family and atmosphere of home.

   Poverty - associated with acting out difficulties in children, lack of resources and parental preparation for achievement, and access to poorer educational opportunities year round. Others argue that lower socio-economic status (SES) parents simply don't place the same emphasis on school, as it may not lead to the same opportunities and chances for success. Minority teens are more likely to drop out of school, or be "transferred" and lost.

   Birth order - this has not been clearly demonstrated, but some argue that the more children in the family, the lower their average IQ. This is explained by the Diminishing Resources Model; the parents only have so much time, attention, affection, and money to invest, and the more children there, the more these finite resources are divided up.

   Malnutrition - research in this area is confused because it's really two kinds of studies; nutrition studies and *mal*nutrition studies. Typically, you take an at risk mother who is pregnant, and put her and the child soon after birth on vitamin and mineral supplements and see if the children fare better compared to a control group. The problem with this is that:

- if the nutrients do a wonderful job of raising the child's potential, and the environment is still poor, you won't detect much difference
- timing for nutrients (typically age 0 - 3 years) is crucial, and good nutrition for 18 months may be canceled out by bad nutrition for 18 months

Childhood trauma and separation from parents - sometimes, the effect is short-term, but if it coincides with testing you might not know it.

Environmental stress - there are numerous studies linking environmental stress to the brain's chemistry, the activation of arousal centers quickly and easily, and the over-taxing of the brain. Other studies link vagal nerve tone (Gottman). The vagus nerve wanders through the abdomen (vagus-vagrant) and when stimulated it inhibits organ arousal and keeps the organism calm. When it works poorly, the organism is more prone to overarousal, which interferes in learning

Parenting - parenting practices also impact IQ scores. A no-nonsense parent who says, "Because I said so, now do it!" (an *Authoritarian* style) is different from the parent who tries to explain and reason (an *Authoritative* style). The second teaches reasoning skills, thought processes to relate behaviors and outcomes likewise for the parent who has time to read to a child at night, play games, take family outings to museums and such.

How does arsenic effect on IQ? The primary routes of As entry into the body are ingestion and inhalation. For soluble trivalent As compounds, approximately 95% of the ingested dose is absorbed from the gastrointestinal (GI) tract. From some previous researches, the amount of As absorbed by inhalation has been determined roughly, and it is thought to be within 60% to 90%. After absorption through the lungs or GI tract, As is widely distributed by the blood throughout the body. As is absorbed into the blood stream at the cellular level and is taken up by

(1) red blood cells,

(2) white blood cells, and

(3) other cells that reduce arsenate to arsenite.

Reduction of arsenate (As V) to arsenite (As III) is needed before methylation can occur. This reaction requires glutathione (GSH). Inorganic As is metabolized via two main types of reaction:

(1) conversion of the pentavalent form of As - arsenate - to the trivalent form arsenite, and

(2) methylation, i.e. addition of a methyl group comprising one atom of carbon and three of hydrogen (-CH3) to the trivalent form

After methylation As can rapidly be eliminated from the body with the urine. There can be large differences between individual humans in their capacity for methylation that is most likely due to differences in enzyme capacity in the body.

Arsenic enters the brain through an, as yet, undefined mechanism. As seems to accumulate in the choroid plexus, perhaps to protect against the entry of As into the brain. In human erythrocytes the anion exchange proteins (bands 1–3) can transport arsenite and arsenate. Arsenite inhibits glutathione reductase and diminishes the intracellular level of reduced glutathione (GSH), which is important in cellular redox balance and protects against oxidative damage by reactive oxygen species (ROS). Brain cells may be at particular risk for oxidative stress (Rodriguez *et al.*, 2005). The brain derives its energy almost exclusively from oxidative metabolism through the mitochondrial respiratory chain, and is relatively deficient in protective mechanisms compared to other tissues, such as liver and kidney.

Damage to the DNA and apoptosis are linked to this arsenite-induced production of hydrogen peroxide, as well as to the induction of nitric oxide and consequent poly (ADP-ribosylation). This damage to DNA is mediated by the methylated species MMA and DMA through ROS production. The mechanisms through which As induces apoptosis are not completely clear, but the enhancement of ROS is followed by caspase activation, down regulation of Bcl-2, release of cytochrome c to the cytosol, activation of CPP32 protease and degradation of poly (ADP-ribose) polymerase (PARP). It has also been proposed that arsenite-produced ROS damage the mitochondrial membrane and activate the mitochondrial permeability transition pore, which leads to cell death. This process has been postulated as a central step in neuronal injury. Indeed, sodium arsenite can induce apoptosis in cortical and cerebellar neurons, involving activation of p38 and JNK3 MAP kinases. Human fetal brain cells exposed in vitro, and neonatal brain cells exposed during gestation to sodium arsenate undergo apoptosis and necrosis, accompanied by increased generation of nitric oxide and other ROS and reduced superoxide dismutase and gluthatione reductase activity (Chattopadhyay *et al.*, 2002; Rodriguez *et al.*, 2005).

Besides the important role of As as an oxidative stress generator, other actions may take place in the CNS and contribute to the observed toxic effects of arsenicals. For instance, in the basal ganglia arsenite exposure induces changes in neurotransmitter levels and alterations of functions reflected in behavioral tests. At the molecular level, arsenite induced stress shares many features with the heat shock response, inducing heat shock proteins of several sizes, including heme oxygenase. This stress response is known to alter patterns of gene expression and appears to modulate the ability of cells to respond to other agents such as cytokines. In the peripheral nervous system, chronic As exposure leads to peripheral neuropathy, while encephalopathy and impairments of superior neurological functions have been reported in patients with acute and occupational exposure to As compounds and in children exposed through environmental pollution.

Acute exposure to As in humans has been shown to result in problems of memory, difficulties in concentration, mental confusion and anxiety (Rodríguez *et al.* 2003). Children chronically exposed to As can experience reduction of IQ and long-term memory loss. Alterations in memory and attention have been recently reported in adolescents exposed to high levels of As (about 200–300 μgL^{-1}) in well water during 8–11 years (Tsai *et al.,* 2003). The neuro chemical studies so far have not provided a solid foundation upon which mechanisms of As neurotoxicity can be elucidated. There is also some information suggesting that children may be less efficient at converting inorganic As to the less harmful organic forms. For this reason, children may be more susceptible to health effects from inorganic As than adults.

Social competence (SC)

"The energy between two people is what creates great marriages, families, teams, and organizations" (Rath, 2006). This so-called energy, also known as friendship, is both an innate and learned process that begins in childhood. Man is a social being. He can not live alone. To make his life easy-going he has to deal with others, interact with others, to fulfill his own needs. Therefore, he has to develop social competence. Social competence is such ability for individuals that lead them to adjust to their society, to solve their social problem normally, to make decision in a crisis situation of the society. When an individual is socially competent, he is able to struggle to fulfill his demands wisely. Most of man's needs can be met only through interaction and relationships with other people; thus, the nature of interpersonal relationships has much to do with the satisfactions one's gains in living. Anyone who has worked with, or raised children knows that at times, children can be selfish or self-centered, hostile or rude, or even standoffish and unapproachable. However, these negative actions or feelings are usually brief and only last a few minutes or hours because children usually learn the skills to be socially competent. Eventually, children realize the differences between socially acceptable and socially unacceptable behavior. Mastering interpersonal social skills at a young age are essential for building and maintaining the complex social networks that one will encounter throughout a lifetime. A positive attitude towards the self and others are also aspects that make for quality social relationships. Children are able to grow into socially competent individuals overtime, and research has found different outcomes in adulthood to be associated with having social competence in childhood. Children who do not develop social competence are lonelier because they are most often rejected by their peers. Additionally, socially incompetent children are more likely to be aggressive to their peers because of this loneliness (Parker and Asher, 1993). Whether an individual is attempting to attract a desired mate, to achieve a happy marriage, to promote a new idea or civic enterprise or simply make friends the outcome is heavily dependent on his competencies for dealing with achieving authentic relationships with others. If he antagonizes people, tries to lean on them exploit them; he is likely to find some of his own deepest psychological needs going unfulfilled. Many people becoming 'unpopular' fail in their attempt to achieve success, ruin their marriage life, bring up maladjusted children, and go through life feeling alone and friendless because they cannot establish satisfying relationships with others (Colman *et al.*, 2003).

Particularly in our highly complex and changing society, the individuals who fail to develop these essential social competences are at a disadvantageous position in coping with the problems of living. Trower *et al.* (1978) maintain that social competence is the possession of social behavioral skills. Regarding social competence the aspect of social behavior plays a major role in the prevention of physical and psychological illnesses. According to it a socially competent person is able to effectively utilize their personal abilities and environmental conditions and has good achievements in their development. There is a similar approach saying social competence enables one to perform the required social behavior, enriching one's interpersonal relations in a way respecting others' interest.

Helmreich *et al.*, (1974) remarked that confidence, dominance, social withdrawal are correlated factors of social competence. A series of experiments have been conducted to find out what factors influence the development of social competence. Three groups of influencing factors have been established: those following from the personality of the individual, factors represented by the family and factors following from the school environment. All the three groups comprise several factors. As regards the factors following from the personality of the individual, the following have positive influence on the development of social competence:

(1) positive self-esteem,

(2) positive attitude,

(3) active cooperation,

(4) tolerance,

(5) efficient communication skills,

(6) good problem-solving abilities,

(7) open personality,

(8) the ability of reconciling personal and group interests

Research has found that an important prerequisite of the development of good social competence is that the individual should have positive self esteem and a positive attitude towards their environment. Tolerance towards others, active cooperation and efficient communication are also important factors of social competence: all these three factors help individuals to be successful in their interaction and, on the basis of the reactions of interacting partner(s), to make the right changes in their social behavior if necessary (Tunstall, 1994). The influential effect of problem solving abilities has become apparent through research conducted by Spivack and Shure (1974), and Rutter (1979). It is positive for the development of social competence if the individual is able to solve problems in creative and alternative ways, while considering both their own interests and those of others. Finally, an open, friendly and cooperative personality also positively influences the development of social competence. When an individual is unable to interact successfully with his own environment, he withdraws himself from the society.

How does social competence developed? According to social psychologists, social competence is developed through appropriate development of socialization of the individual. Socialization is a lifelong process. It starts from the birth and continues until death. The process by which the individual’s behavior and attitudes are brought into harmony with the world is called socialization (Morgan and King, 1993). Penner (1978) states socialization is the process of teaching children the appropriate things to believe and ways to behave in society. It may be mentioned that without the change of attitude and learning behavior, other changes (like physical change) are not socialization only interpersonal attitude and behavior are the results of socialization. Social psychologists have found there are some agents of socialization through which desirable aspects of social development take place. The agents are:

(1) parents and other members in the family

(2) peer groups and community

(3) school, and

(4) mass media

Parents and other members of family are the primary agents to develop child's socialization. Peer groups are such that individual continue his interaction with them and accept their social culture and technique. School is most important agent of socialization to broaden future life of individual. Mass media such as radio, television, etc. is the most important media to learn and to know the other nationwide cultural behavior. The aspect of socialization that concerns us here is family background role socialization - the direct and indirect teaching that the children receive play important role in determining their difference in social competence. Here the role of family socialization play more important role than other agents. It appears from the above discussion that development of social competence is a current social process. Although it was predicted Helmreich *et al.*, (1974) found no relationship between social competence and intelligence as measured by SAT (Scholastic Aptitude Test).

People usually strive for their better adjustment with their family, friends, and social and political institutions, etc. They try to adjust through their whole life and better adjustment is possible only for those who posses better social competence.

Several research works have been conducted to see the social competence, self confidence, dominance, self-esteem, social withdrawal, etc. Sadowski, Woodward, Davis and Elsbury (1983) found TSBI (Texas Social Behavior Inventory) to be significantly related to locus of control for both males and females. High self-esteem was positively associated with internality (Uddin *et al.,* 1991). Helmreich *et al.*, (1974) reported that there was significant relation between male and that of the female self-esteem. Mclntire and Levine (1984) found out the relationship of self-assurance, with performance self-esteem, academic self-esteem, athletic self-esteem, social self-esteem, etc. (Uddin *et al.*, 1991)

Social competence can be best grasped as the combination of several interacting factors. The factors, influencing one another, produce a self-sustaining circular mechanism. Some of the factors may operate almost automatically and greatly stereotypically. Social competence also includes the interpretive system of the individual, or, in other words, their current interests (which latter are referred to as cognitive structures), which change by experience as well as depending on the requirements of the situation. The interests of the individual do not only influence the cognitive information processing procedure but also the behavior of the individual in a given situation. From the above it follows that the following elements of the cognitive procedure are important in the definition of social competence: inner dialogues, expectations, the evaluation of end results, problem solving and other social cognitive abilities and information processing styles (e.g. the creation of information blocks, the use of meta-perspectives, etc.). The type of cognitive processes that one activates in a social situation depends on the maturity of one's information processing procedures, the requirements of the situation, one's current attitudes (interests) as well as the reactions of the other participants. The observable behavior - i.e. what the individual does in a given situation - is only one element (although an important one) of social competence. Yet, the observable behavior is of special significance since it may have personal and interpersonal consequences and the nature of the cognitive processes related to these consequences has further effects on the self-sustaining mechanism. It is also important to note that individuals actively participate in the creation and selection of these mechanisms (whether or not these are intra- or interpersonal mechanisms) and thus actively participate in the formation of their social environment. In the formation of social competence, schools and the solution of cooperative tasks, primarily in pair work or group work, also have a major role (Torgyik, 2005), on condition that the atmosphere is not disturbed by destructive prejudice or the stigmatization or exclusion of certain groups and if there is an intention and the necessary means are available for the constructive formation of inter-group relations (Zoltán et al 2008).

Importance of social competence: There are many advantages of social competence. Socially competent individual is generally accepted by the society in any situation. The society, which possesses people are more competent undoubtedly that society is going to develop rapidly. When an individual falls in a complicated situation, he comes to take advice from the competent people. Thus, we have come to know that socially competent person is self-confident; he does not depend on others. So everyone should try to develop their social competence.

Arsenic and social competence: Arsenic is not only a physical but also a social phenomenon. Besides As toxicity and arsenicosis diseases, As poisoning creates extensive social implications for its victims and their families in affected areas. A number of social problems like social uncertainty, social injustice, social isolation and problematic family issues are reported due to the As poisoning, as depicted schematically in Fig. 1.5. The majority of victims are considered as a burden to their family and society. Some researchers states that the extreme instability of social life in Bangladesh due to the As poisoning. As is producing social stigmatization and discrimination. Unaffected people are generally scared of arsenicosis, therefore they tend to avoid and isolate As victims. Social conflicts over contaminated water destroy the social harmony and network relationships. As victims are often wrongly identified as leprosy patients and isolated from their close relations. In many cases the victims attribute their diseases to their fate. Arsenicosis disease hampers socialization by social stigmatization and discrimination. For instance, As patients often remain ostracized in all age-groups and barred from social activities. Sufferers in rural areas are not allowed to appear in public. Children of arsenicosis patients are not allowed to attend social and religious functions as well as denied to take water from a neighbour's tube well. Affected school-age children are prevented from attending schools and are avoided by their friends and classmates. Affected families are also not allowed to take baths in any of the village ponds. Some unaffected people behave in a hostile manner and think that patients should either stay in their homes or leave the village (Brinkel *et al.*, 2009).

Arsenic victims are abandoned, not only by society but also by their family members. There are some instances that arsenicosis leads to a break-down of the marital relationships. For instance, wives were divorced or separated or sent back to their parents' house because of the arsenicosis disease. There are also some evidences that wives left As affected husbands because they were afraid of arsenicosis. Problems before marriage are also notable. For example, it is difficult to find a spouse for an As victim. Generally people are reluctant to establish marital relationships with those families suffering from arsenicosis. Young women and men in the affected families are advised to remain unmarried (Islam and Isalam, 2007). Such incidents cause unlimited anxiety for both patients and parents of As-affected adult children. The worst affected people in Bangladesh are poor women and children. Arsenicosis women are vulnerable by two ways: firstly by the disease itself and secondly by becoming outcast. Affected women also experience socially undesirable events like dowry, physical torture, and polygamy. Due to the patriarchal system and lower socio-cultural position of women in the society, unmarried women and women abandoned by husband and families live inhumanly.

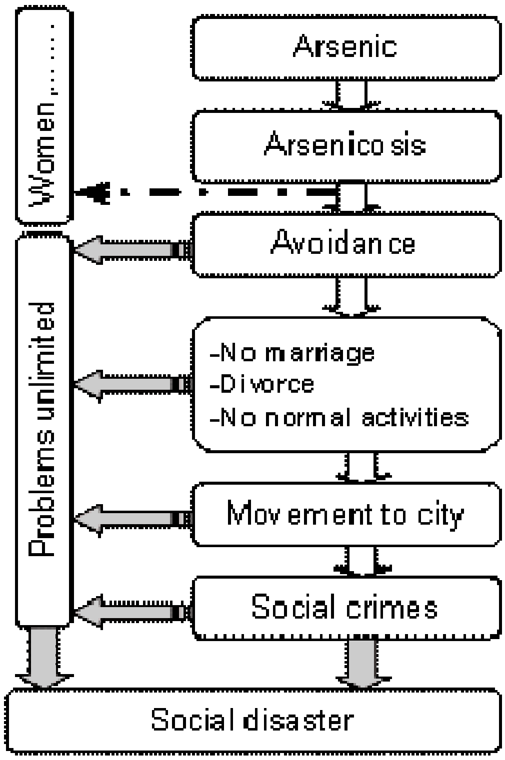


Figure 1.5 Social implications of arsenic poisoning

Some studies describes that a vast majority of the arsenicosis patients expressed their feeling of shame, anxiety, worthlessness, loneliness, and distress. Fear of death, concern for children's future, particularly their daughter's marriage and blaming fare were among others psychological reaction. Moreover the effects of As exposure on social competence have not received much attention yet, so far. Though the affected people have right to be free from As poisoning and get back physical health and honor, and trust to be accepted as members of the community.

1.5 Objectives

Arsenic has some physical problems which are well described, and it has also psychological effects such as anxiety, fear to death, reduction of cognitive function etc. People are not only affected physically but also psychologically and socially. The affected people have right to be free from As poisoning and get back physical and mental health and honor, and trust to be accepted as members of the community. Thus, especial attention is needed to pay to the school going children, because they are growing and developing physically, mentally and socially, although mental development (intelligence quotient) is very hard to evaluate. Very few studies had been conducted on As exposure and children's intellectual function in Bangladesh. In the year of 2004 and 2007, Wasserman *et al.* studied on 6 years and 10 years old children. They found strong association between water arsenic and children's nonverbal IQ. However, Calderon *et al.*, 2001 found an association between verbal IQ and urinary arsenic of the Mexican children. On the contrary, there are very few studies on social implications and arsenic exposure (Hassan *et al.*, 2005, Alam *et al.*, 2002), and to date, there is scarcity of research on arsenic exposure and social competence (SC) of children. Moreover, there are some studies reported the As contamination in food chain (Ohno et al., 2007, Das *et al.* 2004, Huq *et al.*, 2006). In addition, the measurement of water used in cooking is indeed essential to evaluate the relative contribution of different As sources on daily As intake. Therefore, the main focus of the present study is-

- To investigate the relationship between arsenic (As) exposure on intelligence quotient (IQ) and social competence (SC) of children from early childhood to adolescence.

- To assess the amount of food and water used in cooking in order to estimate the total daily As intake.

Chapter II

Arsenic Exposure and Intelligence Quotient or Social Competence of Developing Children

2.1 Study area

Bangladesh officially the People's Republic of Bangladesh is a country in South Asia. It is bordered by India on all sides except for a small border with Burma (Myanmar) to the far southeast and by the Bay of Bengal to the south. Bangladesh is divided into seven administrative divisions, each named after their respective divisional headquarters: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Sylhet, and Rangpur. Divisions are subdivided into districts (zila). There are 64 districts in Bangladesh, each further subdivided into upazila (subdistricts) or thana. In Bangladesh, the people living in 61 out of 64 districts may have been consuming arsenic contaminated groundwater.

My study area was the Narayanganj district of Dhaka division in Bangladesh. The map of Narayanganj district is shown in Fig. 2.1. There are 5 thanas or upazilas in Narayanganj district. Sonargaon which is one of those thanas was our study area. The general and geographical information about the Sonargaon thana are presented in Table 2.1.

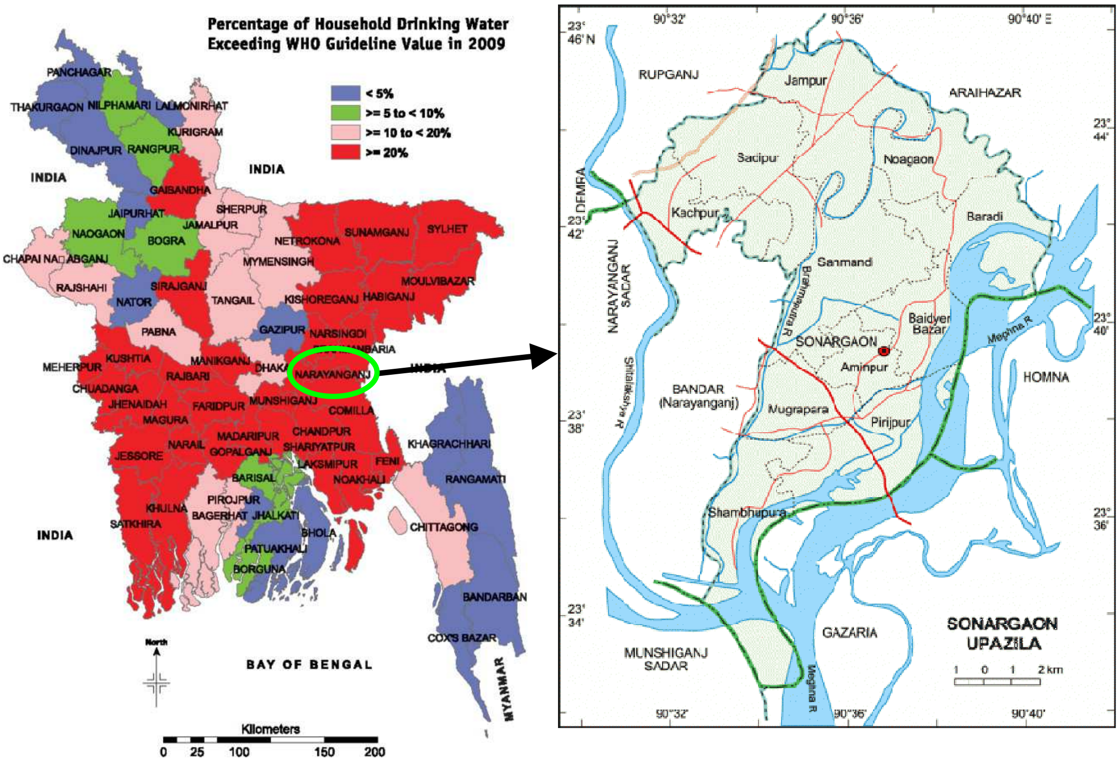


Figure 2.1 Map of Sonargaon thana

Table 2.1 General and geographical information about the Sonargaon thana

Demography	
Thana; union	Sonargaon; Sonmandi
District	Narayanganj
Population	6,405
Household	2,006
River	Brahmaputra
% of As contaminated tube well	89%

Figure 2.2 Some pictorial views of survey area

Most of the house is made by corrugated tin and mud. All the inhabitants use tube well water for drinking purpose and they also use it for other purposes such as cooking, cleaning, washing, etc., as shown in Fig. 2.2.

2.2 Subjects and methods

Most of inhabitants in Narayanganj district depend mostly on subsistence farming for the daily food needs as opposed to market purchases. Most of the people drinking tube well water for accessing ground water in daily life fulfillment. The ground water polluted with severe As poisoning. Total of 720 respondents were children from early childhood to adolescence of different developmental stages. They come from different villages. Detail information about the subject is presented in Table 2.2.

Table 2.2 Detail information about subjects

Sex	Age groups			Total
	4 & 5yrs	9 & 10yrs	14 & 15yrs	
Male	79	110	138	327
Female	97	122	174	393
Total	176	232	312	720

In the present study, the following methodologies were employed to investigate the socio-economic status (SES) as confounding factor, intelligence quotient (IQ) and social competence (SC) of children drinking arsenic contaminated groundwater in Bangladesh. The arsenic concentration in urine and water was considered as a measure of level of contamination. Moreover, physically observed the children's symptoms if any from the arsenic exposure, and also observed the villages for the socioeconomic condition related aspects. The following are detailed descriptions on the methodologies.

2.2.1 Water and urine analyzes

All children were persuaded to provide current drinking water and spot urine samples for the measurement of As concentration in water $[As]_w$ and urine $[As]_u$. Collected samples from each respondent were kept in a freezer and transported to Japan where they were kept at -80°C until element determination. Water samples from each respondent's tubewell were collected in 3.5-ml polyethylene cryovials and were acidified immediately with hydrochloric acid (grade for analysis of poisonous metals, 35%, Wako, Osaka, Japan) at 1% (v/v) final concentration to inhibit deposition of ferric oxide. Urine samples were collected in 2-ml polyethylene cryovials. The collected samples were frozen and transported to Japan where they were kept at -30°C until analysis. To determine the arsenic concentration in water $[As]_w$ or in urine $[As]_u$, all the procedures were performed at the Graduate School of Medicine, University of Tokyo. Urine was diluted 20 times with a mixture of 1% nitric acid (grade for analysis of poisonous metals, 60%, Wako, Osaka, Japan)/2% 1-butanol (grade for HPLC, 99.5%, Nacalai Tesque, Kyoto, Japan). Each water sample or urinary diluent was filtered using a Millex-LH 0.45 μm filter (Millipore, Billerica, MA, USA) connected to a disposable plastic syringe. As concentration was determined by inductively coupled plasma mass spectrometry (Agilent 7500ce ICP-MS, Agilent Technologies, Santa Clara, CA, USA) with an octopole collision/reaction cell. The signal at /m/z/ 75 for arsenic was quantified with helium gas mode. ICP Multi Element Standard Solution (XVI CertiPUR, Merck, Darmstadt, Germany) was used to generate a calibration curve and prepared at three levels ranging from 2 to 50 μg/L in 1% HCl for water or in 1% HNO_3 and 2% 1-butanol for urine. Internal standard solution was prepared in each vehicle with Gallium Standard Solution (grade for AAS, Wako, Osaka, Japan) and monitored at /m/z/ 71 at a concentration of 25 μg/L by online addition via a T-piece. The detection limits (DL) ranged from 1.590 to 2.438 μg/L for arsenic in water and from 0.019 to 1.216 μg/L for arsenic in the 20-fold diluted urine, calculated as the 3SD of the blank vehicles (n=10). The analytical values under the DL were converted to a half value of the DL. For quality assurance, NIST Standard Reference Material 1640 Natural Water, NIST Standard Reference Material 1643e Trace Elements in Water, NIST Standard Reference Material 2670a Toxic Elements in Urine (National Institute of Standards and Technology, Gaithersburg, MD, USA), NIES Certified Reference Material No. 18 Human Urine (National Institute of Environmental Studies, Tsukuba, Japan) and Seronorm Trace Elements Urine (Sero, Billingstad, Norway) were used to validate instrument performance at each running day. The observed concentrations of the reference materials were within the certified range. Urinary creatinine was determined by the Jaffe method using a Lab Assay Creatinine Kit (Wako, Osaka, Japan). The specific gravity of urine was measured by a pocket refract meter PAL-09S (ATAGO, Tokyo, Japan).

The values obtained for $[As]_w$ fall within the range between 0.8 (half value of LOD) and 622 μg/L. Based on some referential levels of $[As]_w$, the subjects were divided into four groups: level-1, level-2, level-3 and level-4. The value of $[As]_w$ for these groups ranged from $0 \leq [As]_w \leq 10$ μg/L, $10 < [As]_w \leq 50$ μg/L, $50 < [As]_w \leq 100$ μg/L and $[As]_w > 100$ μg/L, respectively. The facts that 10 and 50 μg/L are the WHO and Bangladesh national safe levels, respectively, and symptoms are reported among the $[As]_w$ range of 60 to 100 μg/L were taken into account during grouping. In contrast, $[As]_u$ ranged between 6 and 1312 μg/L. The subjects were divided into three groups (low, medium and high) by applying referential levels of $[As]_u$. According to the referential levels, an $[As]_u \leq 137$ μg/L is the so-called 'non-effective level' (Miyazaki *et al.*, 2003), and $[As]_u \geq 400$ μg/L is the 'dermatological level.' The $[As]_u$ values of low, medium and high groups are ranged from $[As]_u \leq 137$ μg/L, $137 < [As]_u \leq 400$ μg/L, and $[As]_u > 400$ μg/L, respectively. There are more referential values, especially among 'non-effective levels'; however, they did not alter the findings observed in this study.

2.2.2 Intelligence quotient (IQ) test

IQ was measured by two kinds of tests: Kaufman Brief Intelligence test and Raven's Standard Progressive Matrices test.

Kaufman Brief Intelligence Test

Kaufman Brief Intelligence Test (KBIT) was used for children from 4 & 5 year age group. It is a brief, individually administrated measure of the verbal and nonverbal intelligence. The verbal score comprises to subtest (verbal knowledge and riddles) and measures verbal, school related skills by assessing a person's word knowledge, range of general information, verbal concept formation, and reasoning ability. The nonverbal score (the matrices subtest) measures the ability to solve new problems by assessing an individual's ability to perceive relationship and complete visual analogies. All matrices items involve pictures or abstract designs rather than words. From a theoretical perspective, the verbal subtest measure crystallized ability and the nonverbal subtest measures fluid reasoning. Age-based standard scores having a mean of 100 and a standard deviation of 15 are provided for the verbal and nonverbal domains and the IQ composite (Kaufman and Kaufman, 2004).

Reliability: Reliability refers to the consistency or dependability of a person's test score. Internal consistency reliability indicates how well a person's performance on this test would generalize to performance on other similar (parallel) tests. If people tend to perform consistently on different sections within the test, this is evidence that all parts of the test are measuring the same ability and that people would likely score similarly on another test of that ability. Test – retest reliability shows how consistently people perform on the same test taken at different items; that is, it reflects the stability of performance. Standard errors of measurement (SEM) by age for the verbal, nonverbal, and IQ composite scores. These SEMs are essentially translations of the internal consistency reliabilities to a more practical metric: the number of point by which the obtained standard score is likely to differ, simply because of measurement error, from the true standard score.

Internal-consistency reliability: Internal-consistency reliabilities were computed for the norm sample using the split-half method. Each subtest was divided into two parallel halves, each of which had a similar distribution of item difficulties and representation of content (e.g, vocabulary and information items on verbal knowledge).

Interpreting KBIT scores: Raw scores cannot be interpreted directly. It needed to be converted to derived scores that have uniform meaning from test to test and from age to age. Standard scores in KBIT are the most satisfactory type of derived score from most point of view. A standard score tells how far the individual's raw score is from the average raw score of people in the population who are of the same age, taking into account the standard deviation (degree of variability) of the distribution of raw scores in the population. However, although standard scores have excellent psychometric properties, they frequently are not understood by examinees, parents, teachers, and others who are interested in the results of the evaluation. Both percentile ranks and descriptive categories can facilitate the communication of test results. Moreover, since the description sometimes will communicate better than numerical score (e.g. standard score or IQ percentile rank), especially for people who are uncomfortable with numbers, conversion of IQ score to a descriptive category is beneficial. Descriptive categories in KBIT for standard score are presented in Table 2.3.

Table 2.3 Descriptive categories in KBIT for children

Range of standard score	Descriptive category
131 or greater	Upper extreme
116-130	Above average
85-115	Average
70-84	Below average
69 or less	Lower extreme

Raven's Standard Progressive Matrices test

Raven's Standard Progressive Matrices (SPM) test was used to assess the IQ of children from 9 & 10 year and 14 & 15 year age groups, and the test was conducted in the school. It is a group test, and can be described as "test of observation and clear thinking". Each problem in the test is really the "mother" or "source" of a system of thought, while the order in which the problems are presented provides training in the method of working. Hence the name is "Progressive Matrices". The first form of the Progressive Matrices test to be developed was the standard series. This was designed to cover the whole range of ability from low-scoring respondents and young children, through high-scoring adults, to those of old age. The SPM was developed for use in homes, schools, and workspaces (where testing conditions and levels of motivation are often far from a psychometric point of view) as well as in laboratories. It had therefore to be simultaneously short, attractive, robust, and valid.

The test is made up of five sets, or series, of diagrammatic puzzles exhibiting serial change in two dimensions simultaneously. Each puzzle has a part missing, which the person taking the test has to find among the options provided. The SPM was designed to cover the widest range of mental ability and to be equally useful with persons of all ages, whatever their education, nationality, or physical condition. The standard test consists of 60 problems divided into five sets (Set A, B, C, D, and E), each made up of 12 problems (Raven *et al.*, 2000). Each set starts with a problem which is, as far as possible, self-evident, and develops a theme in the course of which the problems build on the argument of what has gone before and thus become progressively more difficult. This procedure provides the respondent with five opportunities to become familiar with the field and method of thought required to solve the problems. Administered in the standard way, the test therefore provides a built-in training Programme and indexes the ability to learn from experience or “learning potential”. The cyclical format also provides an opportunity to assess the consistency of a person’s intellectual activity across five successive lines of thinking. The test length was carefully constructed to be just sufficiently long to assess a person’s maximum capacity for coherent perception and orderly judgment without being too exhausting or unwieldy. Use of the SPM with an overall time limit which does not enable everyone to finish results in an uneven and invalid distribution of scores. In such circumstances, some people spend a lot of trying to solve the more difficult problems in the early sets while others skip over them and greatly enhance their scores by correctly solving the easier items of later sets.

All respondents, whatever their age, are given exactly the same series of problems in the same order and asked to work at their own speed, without interruption, from the beginning to the end of the test. As the order of the problems provides the standard training in the method of working, the test can be given as an individual, a self-administrative, or a group test. A person's total score provides an index of intellectual capacity. The consistency between the contributions which each of the sets makes to the total indicates the reliability of the estimate. If this is not satisfactory, tracing the source of inconsistencies provides a means of exploring the psychological significance of the discrepancies. Young children, mentally handicapped persons, and very old people are not expected to solve more than the problems in sets A and B of the test and the easier problems of sets C and D, where reasoning by analogy is not essential.

The standard progressive matrices were originally developed in the mid-1930s. It was revised and standardized in Ipswich in 1938. Extensive adult norms were collected during the Second World War, and the test was again standardized, along with the Mill Hill Vocabulary (MHV) scale, on school children in Colchester in 1943. Additional data on old people and others were accumulated during the Forties. During the Fifties and Sixties several checks were run on the accuracy of the norms. In 1979, a nationally representative sample of 3,500 British schoolchildren aged 6 to 16, excluding those attending special schools, was tested. Between 1984 and 1986 a series of local norming studies was carried out in school districts throughout the United States of America. Many new norms on young people were collected from all over world between 1979 and 2000.

Reliability and validity of SPM: Over 40 studies dealing with the reliability of the SPM have been reported in the literature. They cover a very wide age-range, many cultural groups, and clinical as well as normal populations. When these studies are excluded, the general picture is of good reliability. However, the concurrent and predictive validities of the SPM vary with age, possibly sex, and homogeneity of the sample, and the conceptual relevance of the criterion to which the SPM will be related and the quality of its assessment.

Evaluating and reporting results: It is possible to classify a person according to the score obtained as shown below in Table 2.4:

Table 2.4 IQ grades and descriptive categories in Raven's Standard Progressive Matrices test

Percentile	Grade	Grade description
5	V	Intellectually defective
10	IV-	Below average in intellectual capacity
25	IV	Below average in intellectual capacity
50	III	Intellectually average
75	II	Above the average in intellectual capacity
90	II+	Above the average in intellectual capacity
95	I	Intellectually superior

2.2.3 Social competence (SC) test

The Texas Social Behavior Inventory (TSBI) which is simply a survey type investigation has been employed in studying the social competence among students. The questionnaire which is a Bengali version of TSBI Form-A by Helmreich *et al.*, (1974) on social behavior, was administered on the children, who are from five different villages at Sonargong and Araihazar Thana of Narayanganj district, are from 14 & 15 year and 9 & 10 year age groups. The original 'TSBI' is in English. Without changing the meaning, the original scale was translated into Bengali to gain better result. The original 'TSBI' consisted to 32-items selected from a larger pool on the basis of factor and item analyses. Shortly after the creation of the scale, two parallel 16-items forms were prepared. This split is based on the desire for rapid administration and for use in studies attempting to change self-esteem. Most researchers using the TSBI have employed one of the short forms. In this study Form-A which contains 16-items was used. There are 5-items worded negatively. The remainders are positively worded.

The TSBI is self-administering in nature. Subjects were requested to respond to declarative statements for which there are five response alternatives using a five-point Likert type format (not at all characteristic of me, not very, slightly, fairly, very much characteristic for me). All items are given scores ranging from 0 to 4 with 0 defining the response associated with low social competence and 4 the response characteristic of high social competence. The total score for each subject is the sum of all items giving a possible range of 0 to 64 with higher scores indicating higher competence.

Reliability and validity of the TSBI:

Internal consistency: Alternate-form reliability of the total 32-items scale is .89 (Helmreich & Stapp, 1974). McIntire and Levine (1984) reported a Cronbach · of .92 for the full 32-items version.

Test-retest: No test-retest correlations were encountered.

Validity*:* Sadowski, Woodward, Davis, and Elsbury (1983) found the 'TSBI' to be significantly related to locus of control. For validity, co-efficient of correlation were calculated based on a sample of more than 1000 college students. For both males and females, high self-esteem was positively associated with internality. Helmreich *et al.*, (1974) reported that 'TSBI' scores were correlated 0.81 with masculinity for male and 0.83 for females.

*Scoring of the 'TSBI' Form-A***:** It has already been stated that the 'TSBI' Form-A contains 16-items of which 5-items constitute worded negatively and the rest 11-items are positively worded (Helmreich *et al.*, 1974). Individual items are keyed from 0 to 4 as shown in Table 2.5, and scores on the scale range from 0 to 64 with higher scores indicating higher competent.

Table 2.5 Scoring of Texas Social Behavior Inventory (TSBI) Form-A

Type of response	Score
Not at all characteristic of me	0
Not very	1
Slightly	2
Fairly	3
Very much characteristic of me	4

2.2.4 Statistical analysis

Data were entered into SPSS for Windows, version 18. One-way analysis of variance (ANOVA) was employed for analyzing the differences between the groups of the transformed data, whereas analysis of covariance (ANCOVA) was used to measure the effect of arsenic concentrations in water $[As]_w$ and urine $[As]_u$ on measured IQ and SC by controlling for the socioeconomic indicators. Moreover, linear regression was used to predict the relationship between $[As]_w$ and $[As]_u$.

2.3 Arsenic exposure vs. IQ and SC of children

Information about socio-demographics of the respondents is summarized in Table 2.6. Approximately 50% of the houses in the survey area are made of corrugated tin on wall and roof. The households are mainly engaged in farming and wage labor. Though a considerable number of households were in the businessman category, they are actually engaging in a very small business like vegetable selling, shop keeping, etc. Bangladesh is a developing country with the majority of households falling into the low income stratum. Thus, the participating households in this study belonged to low to low-medium strata. More than 20% of the respondents are illiterate, and 37% just attended in the primary education.

In general, the results presented in Table 2.6 indicate that most of the respondents came from families with poor socioeconomic status (low and low-medium income). Investigating the influence of socioeconomic status on As contamination the one way ANOVA test was performed, and the result stated that $[As]_u$ significantly differed by parental income (p<0.01 for 14 & 15 years, p<0.05 for 9 & 10 years and p<0.05 for 4 & 5 years age groups children). It suggests that socio-demographic conditions have an influence on As exposure, and the respondents with poor socioeconomic status are consuming highly As contaminated tubewell water and individuals with higher income can take preventive measures. However, there was no significant relationship exhibited between the As contamination ($[As]_u$) and other socioeconomic indicators like education, sanitation and house type, etc.

Table 2.6 Sample characteristics [No. (%)]

Variable	No. (%)
House type	
Soil wall & tin roof	88(12.2)
Corrugated tin wall & roof	360(50)
Brick wall & tin roof	260(36.1)
Occupation of household head	
Wage labor	151(21.0)
Farmer	115(16.0)
Business	223(31.0)
Paid jobs	122(17.0)
Others	101(14.0)
Income of household head	
Low	264(36.7)
Low-medium	282(39.2)
Medium	166(23.1)
Education of household head	
Illiterate	152(21.1)
Primary	264(36.7)
Secondary	230(31.9)
Higher secondary & above	65(9.0)

2.3.2 Relationship between arsenic exposure and IQ of children (≥4 years old)

<u>14 & 15 years group children</u>

The percent distributions of the IQ grades for the three urinary As ($[As]_u$) groups (low, medium and high; as shown in Fig. 2.3) indicated that a very small percentage of the respondents from high $[As]_u$ groups possessed above average intellectual capacity (> grade III), with most having average and below average IQ grades. In contrast, a comparatively higher percentage of the respondents from low $[As]_u$ groups possessed above average intellectual capacity.

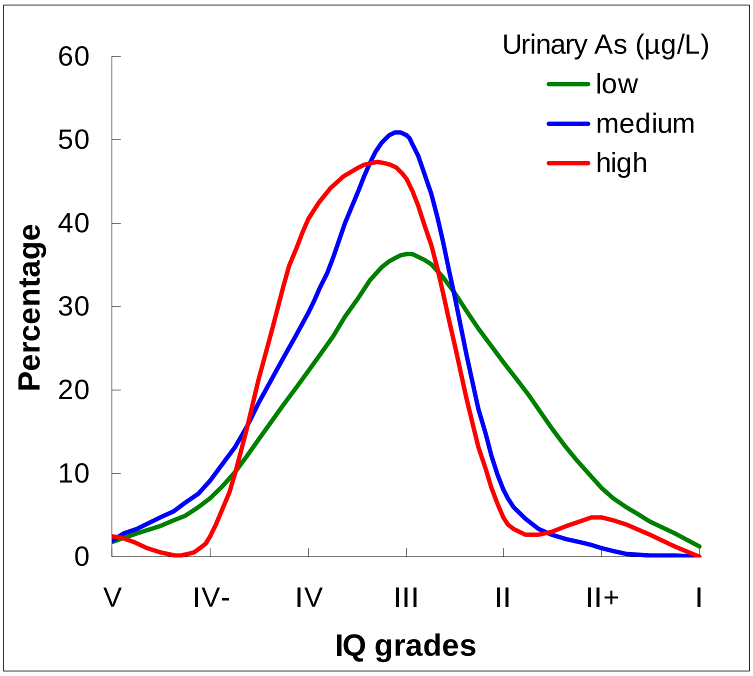


Figure 2.3 Percentage distribution of the IQ grades for the three $[As]_u$ groups (14 & 15 year age group)

The predicted means and standard deviations of the IQ percentile for three $[As]_u$ groups are presented in Table 2.7. One-way ANOVA was applied to assess the differences in mean and variance, and the results indicated that the IQ percentile significantly differed among the $[As]_u$ groups ($p<0.01$). A post-hoc analysis for multiple comparison revealed that high ($p<0.05$) and medium ($p<0.01$) levels of $[As]_u$ significantly lowered the mean IQ percentile compared with the low $[As]_u$ level, and the IQ in the high $[As]_u$ group did not differ from that in the medium $[As]_u$ group. Finally, controlling socioeconomic covariates the ANCOVA revealed that there was a significant effect of $[As]_u$ on the IQ ($p<0.01$).

Table 2.7 IQ in different $[As]_u$ groups (14 & 15 year age group)

Urine As (μg/L) groups	IQ percentile (Mean ± SD)
low (*n*=171)	50.5 ± 24.3[b]
medium (*n*=99)	40.6 ± 18.7[a]
high (*n*=42)	40.9 ± 19.3[a]

a, b - values with different letters within the same column are statistically different

We further investigated the effect of As concentration in water $[As]_w$ on IQ. The mean IQ percentile (52.2 ± 21.4) presented in Table 2.8 for the L1 $[As]_w$ group was higher than that of other groups. However, the mean IQ scores among the L2, L3 and L4 $[As]_w$ groups were nearly the same. It was found that $[As]_w$ had a significant influence on IQ ($p<0.01$). A planed contrast indicated that the mean IQ score of the L1 group significantly differed from the L2 and L4 groups at $p<0.05$ and $p<0.01$, respectively. Moreover, the mean IQ percentile in the L4 group was significantly lower than in the L1 group ($p<0.01$). Finally, controlling for socioeconomic indicators such as parental education, occupation and income, the ANCOVA revealed that there was a significant effect of $[As]_w$ on IQ ($p<0.01$). This indicates that the consumption of a high concentration of As through groundwater significantly lowered the mean IQ of the children.

Table 2.8 IQ in different $[As]_w$ groups (14 & 15 year age group)

Water As (μg/L) groups	IQ percentile (Mean ± SD)
L1 (*n*=120)	52.2 ± 21.4[b]
L2 (*n*=44)	43.4 ± 22.6[a]
L3 (*n*=52)	44.0 ± 22.6[a]
L4 (*n*=96)	40.7 ± 22.3[a]

a, b - values with different letters within the same column are statistically different

9 & 10 years group children

Figure 2.4 shows the percent distributions of IQ grades for 3 (three) $[As]_u$ groups (low, medium and high), and indicated that a very small percentage of the respondents from high $[As]_u$ and medium $[As]_u$ groups possessed above average intellectual capacity (> grade III); mostly bearing below average IQ grades. In contrast, a comparatively higher percentage of the respondents from low $[As]_u$ groups possessed above average intellectual capacity, and around 40% of the respondents bearing average IQ grades. One way ANOVA was applied to assess the differences in mean and variance, and the result presented in Table 2.9 indicated that IQ percentile significantly differed among the $[As]_u$ groups for 9 & 10 year age group children ($p<0.001$). After controlling socioeconomic covariates the ANCOVA revealed that there was a significant effect of $[As]_u$ on the IQ (p<0.001).Here, it can be mentioned that a similar effect of As concentration in water $[As]_w$ on IQ was experienced for 9 & 10 year age group like what observed in 14 & 15 year age group children.

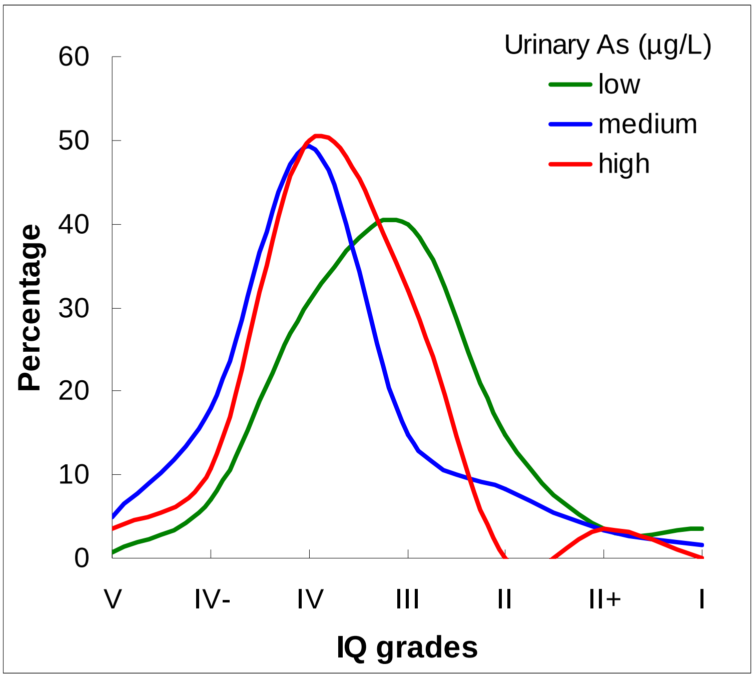


Figure 2.4 Percentage distribution of the IQ grades for the three $[As]_u$ groups (9 & 10 year age group)

Table 2.9 IQ in different $[As]_u$ groups (9 & 10 year age group)

$[As]_u$ (µg/L) groups	IQ percentile (Mean ± SD)
low (*n*=143)	45.8 ± 22.9[b]
medium (*n*=61)	32.4 ± 23.0[a]
high (*n*=28)	33.9 ± 19.8[a]

a, b - values with different letters within the same row are statistically different

4 & 5 years group children

The percent distributions of the nonverbal IQ grades for 3 (three) $[As]_u$ groups (low, medium and high) shown in Fig. 2.5 indicated that a major percentage of the respondents from high $[As]_u$ groups possessed below average grade. In contrast, 50% or more respondents from low and medium $[As]_u$ groups possessed average nonverbal IQ grades. One way ANOVA was applied to assess the differences in mean and variance, and the result indicated that nonverbal IQ percentile significantly differed among the $[As]_u$ groups for 4 & 5 year old age group only the nonverbal ($p<0.05$) percentile significantly differed among the $[As]_u$ groups. A post-hoc analysis for multiple comparison as shown in Table 2.10 states that a significant reduction in the nonverbal IQ percentile was found in the high ($p<0.01$) $[As]_u$ groups in comparison with the low and medium $[As]_u$ group.

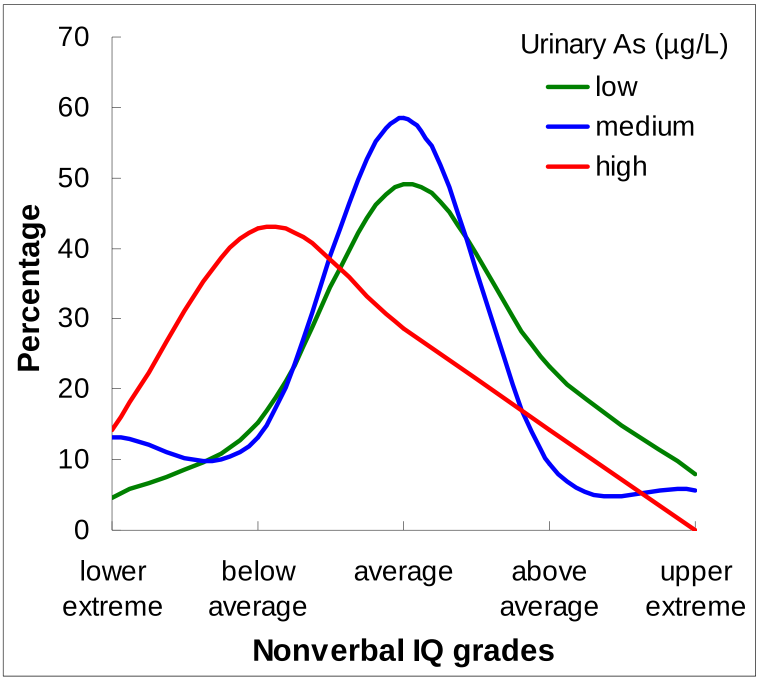


Figure 2.5 Percentage distribution of the nonverbal IQ grades for the three $[As]_u$ groups (4 & 5 year age group)

Table 2.10 Nonverbal IQ percentiles in different $[As]_u$ groups (4 & 5 year age group)

$[As]_u$ (μg/L) groups	IQ percentile (Mean ± SD)
low (*n*=112)	57.6 ± 34.7[b]
medium (*n*=53)	45.9 ± 35.3[b]
high (*n*=7)	19.0 ± 18.4[a]

a, b - values with different letters within the same row are statistically different

Finally controlling socioeconomic covariates the ANCOVA revealed that there was a significant effect of $[As]_u$ on the IQ ($p<0.05$).

2.3.3 Relationship between arsenic exposure and SC of children (≥ 9 years old)

<u>14 & 15 years group children</u>

The percent distribution of SC for the $[As]_u$ groups in Fig. 2.6 illustrates that a higher percentage of children who were averagely social competent scored between 31 and 45. A very small percentage (approximately 4 to 5%) of the children from high $[As]_u$ groups possessed high social competence (scored above 45). Comparatively, a high percentage of the children from the high $[As]_u$ group scored below 30, which indicates poor social competence.

The mean scores and standard deviation of SC shown in Table 2.11 indicated that the score differed among the $[As]_u$ groups (low, medium and high). Moreover, one-way ANOVA confirmed that SC significantly differed in the $[As]_u$ groups ($p<0.001$), and a multiple comparison post-hoc analysis clarified that a significant reduction in the score of SC was found in the medium ($p<0.001$) and high ($p<0.01$)

$[As]_u$ groups in comparison with the low $[As]_u$ group. Moreover, a significant effect of $[As]_u$ on the SC score (p<0.001) was identified after controlling for the socioeconomic indicators.

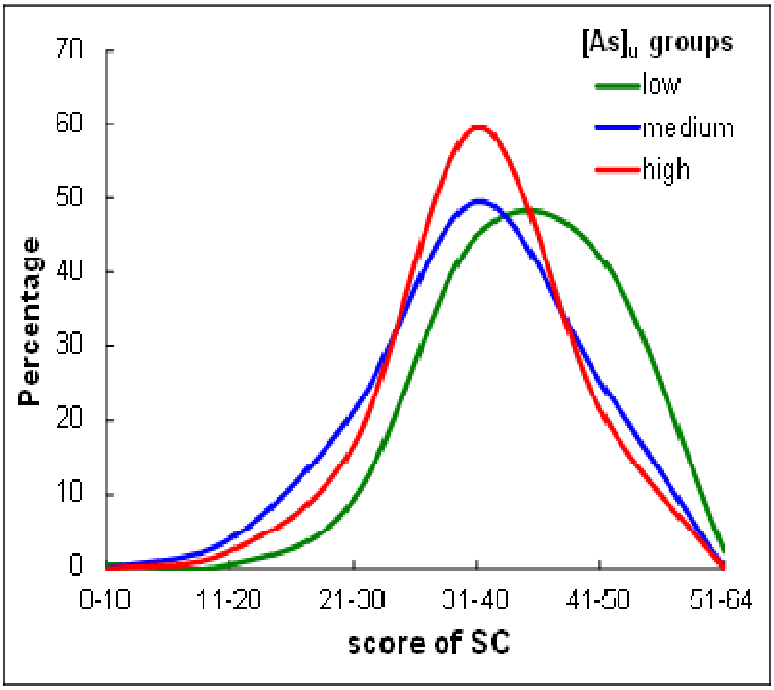


Figure 2.6 Percentage distribution of the SC scores for the three $[As]_u$ groups (14 & 15 year age group)

Table 2.11 SC in different $[As]_u$ groups (14 & 15 year age group)

Urine As (μg/L) groups	Score of SC (Mean ± SD)
low (*n*=171)	39.0 ± 6.6[b]
medium (*n*=99)	35.2 ± 7.0[a]
high (*n*=42)	34.7 ± 6.2[a]

a, b - values with different letters within the same column are statistically different

We further investigated the effect of As concentration in water $[As]_w$ on SC and the result is presented in Table 2.12. The similar trend in the mean SC scores was found among the $[As]_w$ groups and $[As]_u$ groups. SC significantly differed in the $[As]_w$ ($p<0.05$) groups, and the mean SC score in group L4 significantly differed from the L1 group ($p<0.05$). However, no significant effect of $[As]_w$ on SC was found after controlling for the socioeconomic indicators.

Table 2.12 SC in different $[As]_w$ groups (14 & 15 year age group)

Water As (μg/L) groups	Score of SC (Mean ± SD)
L1 (*n*=120)	38.6 ± 5.6^{b}
L2 (*n*=44)	$37.6 \pm 7.6^{b, a}$
L3 (*n*=52)	36.1 ± 9.0^{a}
L4 (*n*=96)	35.9 ± 6.5^{a}

a, b - values with different letters within the same column are statistically different

9 and 10 years group children:

Figure 2.7 shows the percent distribution of SC for the $[As]_u$ groups, and illustrates that more than 50% children from each group were scored between 31 and 40, and approximately 15% of the children from low $[As]_u$ groups possessed high social competence (scored above 45). The mean score of SC presented in Table 2.13 indicates that they differed among the $[As]_u$ groups (low, medium and high), and one-way ANOVA also confirmed this findings ($p<0.05$). A multiple comparison post-hoc analysis clarified that a significant reduction in the score of SC was found in the high ($p<0.01$) $[As]_u$ groups in comparison with the low $[As]_u$ group. Moreover, a significant effect of $[As]_u$ on the SC score (p<0.01) was identified after controlling for the socioeconomic indicators. Here, it is mentioned that further investigating the effect of As concentration in water $[As]_w$ on SC for 9 & 10 year age group, a similar effect like 14 & 15 year age group children was observed.

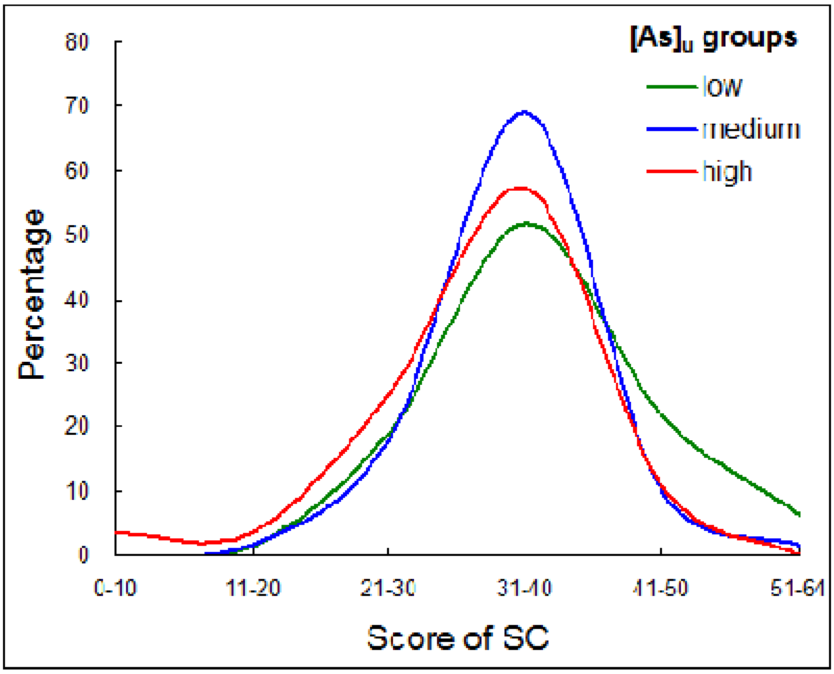


Figure 2.7 Percentage distribution of the SC scores for the three $[As]_u$ groups (9 & 10 year age group)

Table 2.13 SC in different $[As]_u$ groups (9 & 10 year age group)

$[As]_u$ (μg/L) groups	SC score (Mean ± SD)
low (n=143)	36.7 ± 7.6^{b}
medium (n=61)	$34.6 \pm 6.1^{a, b}$
high (n=28)	32.0 ± 7.8^{a}

a, b - values with different letters within the same row are statistically different

2.4 Summary

From the result it is indicated that urinary As was negatively associated with IQ of children from early childhood to adolescence. And urinary As was negatively associated with SC of children from late childhood to adolescence. A high concentration of $[As]_w$ or $[As]_u$ was associated with lowering the IQ percentile and SC scores.

Chapter III

Arsenic Intake from Cooking Water and Food

As mentioned in the earlier chapter men ingested arsenic to their body mainly by ingestion through drinking/cooking water and food stuffs (e.g. rice). Because food prepared with high-arsenic water and food crops irrigated with contaminated water contribute to total daily As intake.

3.1 Study area

Measurement of water used for cooking under different cooking process was conducted among respondents in the area of Sonargaon thana, from different villages.

Rice samples were collected to determine the arsenic concentrations in rice as a source to total arsenic intake. As content of 129 rice samples were collected from 18 districts, both exposed and non-exposed areas, in Bangladesh.

3.2 Samples and methods

The amount of water used in cooking was measured with a food preparation survey on site. The amount of water used for food preparation was measured by visiting each household. Most households in the present survey area cook food twice in a day: once in the early morning and again in the evening. Very few of the households cook food at lunch. These measurements were either performed if the respondents were found cooking or on the next day after requests for them to cook while we were around. Raw foodstuffs and water used for cooking one meal were measured using a food weighing machine and beaker, respectively.

Rice sample test

Arsenic concentration in rice was determined by Varian AA220 Atomic Absorption Spectrometer. The procedure that is followed during analyzing the rice samples is as follows:

Placing test portion in previously cleaned Vycor evaporating dish (which may contain 5g filter pulp for ease of handling). Exact amount of composite required will depend on concentration of minerals present. (For powders, take ≥1.5g.) In general, 25ml will be adequate. If some minerals, in particular Fe, Cu, or Mn, are at very low levels, a larger aliquot (≤50.mL) may be necessary.

Drying aliquot in 100℃ oven overnight or in microwave oven (programmed over ca 30 min). When dry, heat on hot plate until smoking cases, and then place dish in 525℃ furnace (carefully avoiding ignition) for minimum time necessary to obtain ash that is white and free from C, normally 3-5 h, but ≤8 h. Remove dish from furnace and let cool. Ash should be white and free from C. If ash contains C particles (i.e, it is gray), wet with H_2O and add 0.5-3 mL HNO_3. Dry on hot plate or steam bath and return dish to 525℃ furnace 1-2 h.

Dissolve ash in 5 mL IM HNO_3, warning on steam bath or hot plate 2-3 min to aid in solution. Add solution to 50 mL volumetric flask and repeat with 2 additional portions of IM HNO_3.

3.3 Relationship between arsenic in urine and tubewell water

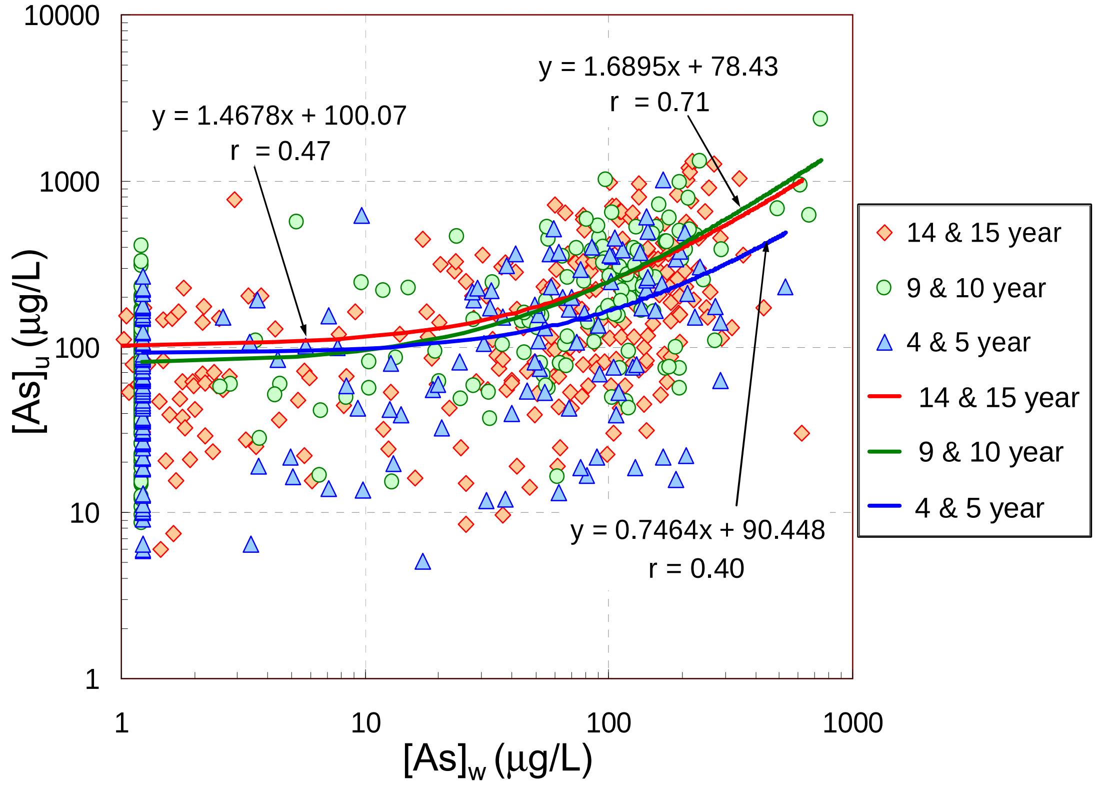


Figure 3.1 Relationship between the urinary ($[As]_u$) and drinking water ($[As]_w$) As concentrations

The relationship between the individual urinary ($[As]_u$) and drinking water ($[As]_w$) As concentrations were analyzed, and the results are presented in Fig. 3.1. Positive correlations for 14 & 15 year (Pearson r = 0.71, p<0.01), 9 & 10 year (Pearson r = 0.47, p<0.01), and 4 & 5 year (Pearson r = 0.4, p<0.01) age groups children were identified between $[As]_w$ and $[As]_u$; both variables were converted into their respective logarithmic values. It is apparent that in the lower $[As]_w$ range (up to 10 µg/L) for all age groups, the contribution of tubewell water to arsenic intake is small in comparison to other unknown sources. Moreover, the results indicated a relatively constant value in $[As]_u$ up to 10 µg/L of $[As]_w$. When $[As]_w$ exceeds 10 µg/L, the deviation also increases rather than remaining constant. This suggests the existence of other sources of arsenic intake.

3.4 Relative contribution of cooking water to arsenic intake

To identify other sources of As, food consumption patterns were assessed by weekly food frequency questionnaire (FFQ) and the 24hour recall method. From these questionnaires, we divided the food items into some categories such as carbohydrate, leafy vegetables, non-leafy vegetables and root and tubers. In this area, the leafy vegetables consumed are similar to that consumed in Japan. Besides them there are varieties of leafy vegetables such as Halancha leaf, Amaranth leaf, Indian spinach, Arum leaf, as shown in Fig. 3.2. There are varieties of locally available non-leafy vegetables and root-tubers consumed by the respondents shown in Fig. 3.3 and 3.4, respectively.

Figure 3.2 Leafy vegetables

Figure 3.3 Non-leafy vegetables

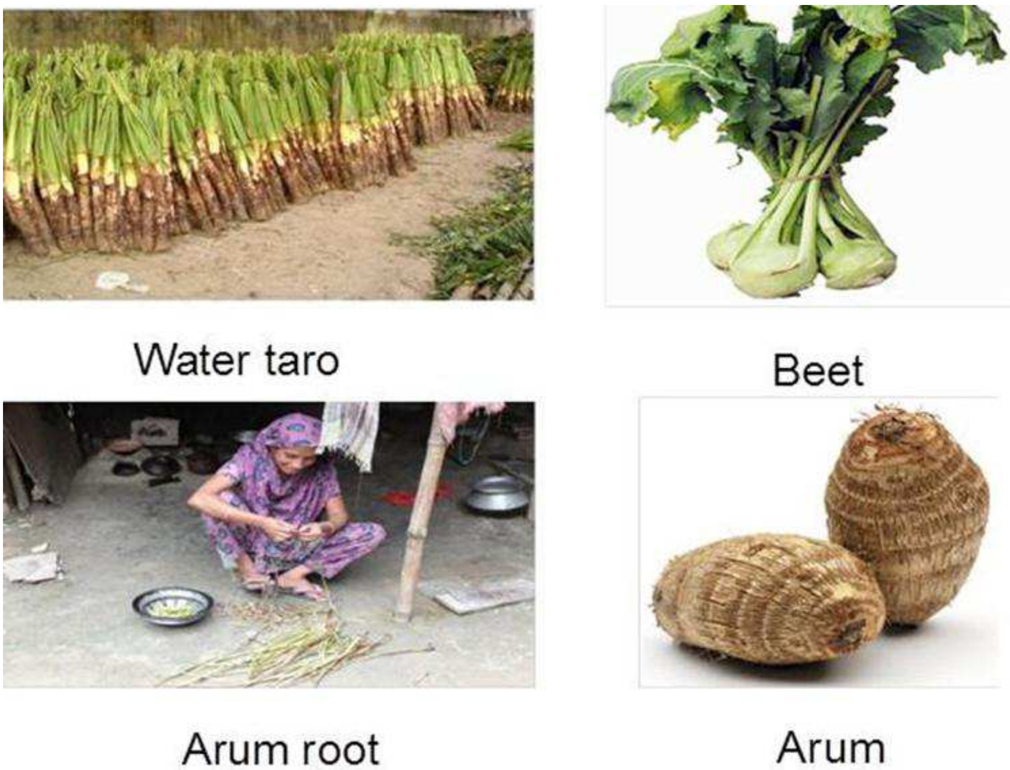
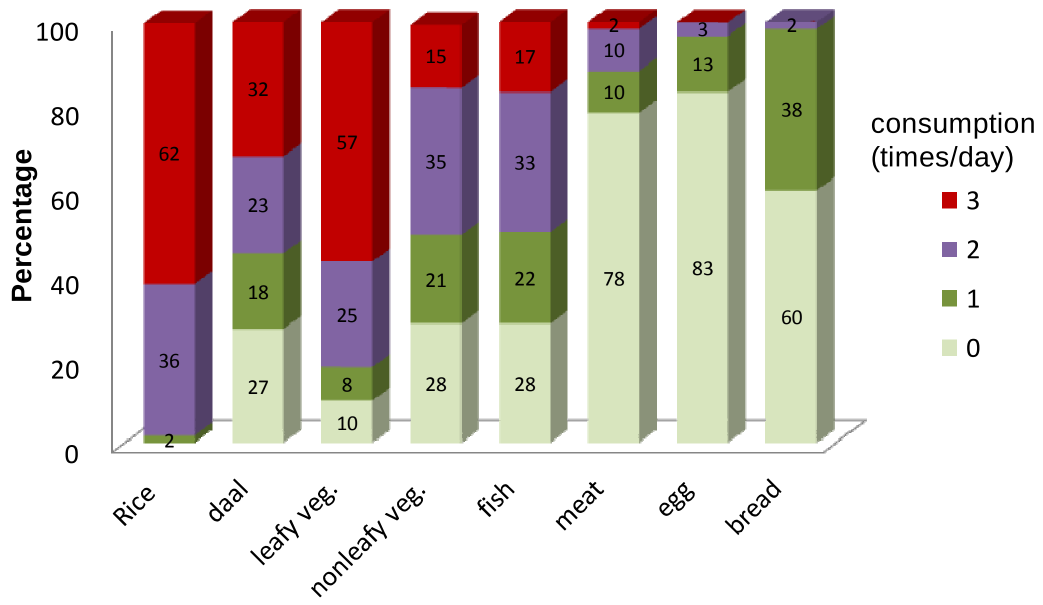


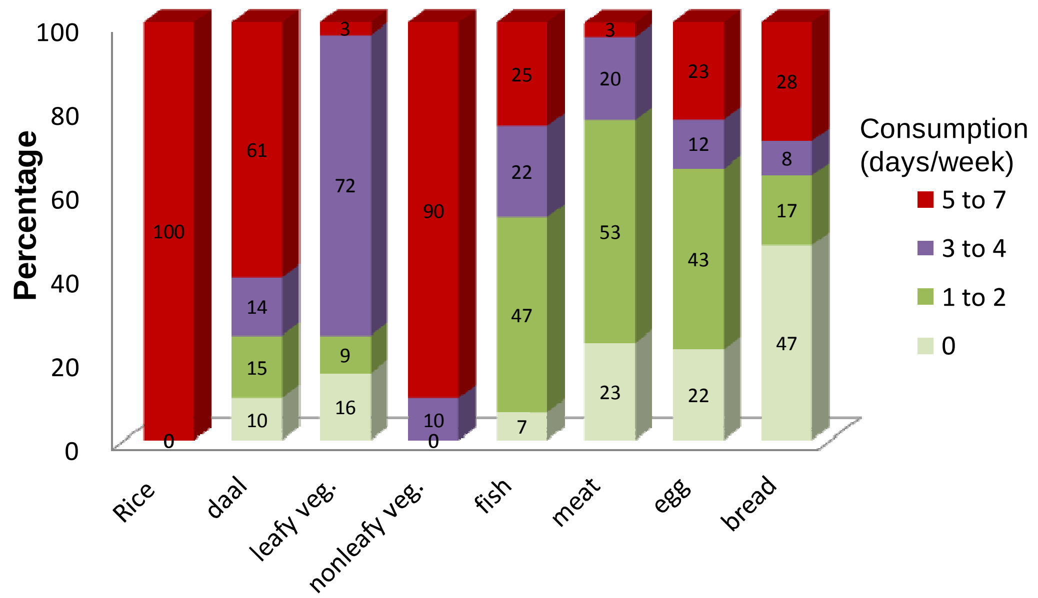
Figure 3.4 Root and tuber vegetables

Food consumption by 24hour recall and weekly-FFQ

According to the 24-hr recall method (Fig. 3.5(a)), 62% of the respondents consumed rice and 32% consumed daal three times per day. While the FFQ results (Fig. 3.5(b)) indicated that 100% of respondents consumed rice five to seven days per week, followed by non-leafy vegetables (90%) and then daal (61%).



(a) 24 hour recall



(b) Seven day- FFQ

Figure 3.5 Food consumption

The amount of water used in cooking was measured with a food preparation survey on site (Table 3.1). Rice, the major Bangladeshi food, is usually cooked with either “fixed water” or “excess water.” In the former process, water is added at approximately 2.5 times the volume by weight of rice. The rate is much higher than the 1.3 used in Japan (Watanabe *et al.*, 2004). In the excess water process, water is added at approximately three to four times the volume by weight of rice, and when the rice is boiled, the excess water is discarded. In our study area, most of the households cooked rice with “excess water.” As shown in Table 3.1, an average of 1,165 mg of rice was boiled with 3,827 ml of water initially. After discarding the excess water, 3,312 ml of water (approximately 2.8 times the volume by weight of the rice) was absorbed in the cooked rice. Curry is the most common cooking recipe including either meat or fish or egg or vegetables. A large amount of water is also required when cooking curry. Another common recipe is daal soup with different types of pulses/lentils. Water is not discarded after cooking either curry or daal soup. As for daal soup, the ratio of lentils to used water is approximately 1/6, whereas the ratio for vegetables is 1/0.8. Based on the data obtained from 24-hr recall and FFQ, the weekly consumption of water from cooked foods was estimated. As shown in the right-most column, the major source of water consumption was cooked rice, followed by daal soup. The contribution of water from different types of curry and chapatti was minor because they were not often consumed.

Table 3.1 Water added in cooking foods and estimated water consumption[§] (ml/person/week) by recipe

Foods	Amount (g)	Water added (ml)	Actual added water (ml) [Relative difference]	Water consumption (ml/person/ meal)	Water consumption (ml/person/ week)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Rice (n=443)	1,111 ± 386	3,632 ± 1,189	3,156 ± 1,121 [2.84]	629 ± 153	9,882 ± 3,126
Daal soup (n=443)	235 ± 119	1,409 ± 628	1,409 ± 628 [6.0]	278 ± 78	2,930 ± 1,405
Vegetable curry (n=431)	555 ± 297	425 ± 226	425 ± 226 [0.8]	88 ± 50	943 ± 469
Fish curry (n=249)	462 ± 200	489 ± 251	489 ± 251 [1.06]	106 ± 61	677 ± 268
Meat curry (n=164)	891 ± 355	888 ± 424	888 ± 424 [1.0]	200 ± 122	588 ± 160
Egg curry (n=112)*	5 ± 1.7	329 ± 186	329 ± 186 [1.66]	78 ± 40	319 ± 168
Chapatti (n=77)	727 ± 390	224 ± 106	224 ± 106 [0.31]	48 ± 23	169 ± 97

* assuming 1 Egg = 40 g

§ based on data obtained from 24-hr recall and FFQ

3.5 Arsenic in staple food (rice)

From the pathway of arsenic exposure to human body it was shown that arsenic enters to human body indirectly by grain or vegetables. From the results of 24H recall and food frequency questionnaire (FFQ) it was indicated that rice is mostly consumed food by the respondents. Thus, the food stuff, especially rice, as the source of arsenic cannot be overlooked.

Rice is the staple food in Bangladesh. In Bangladesh, large scale use of groundwater for irrigation began with the "green revolution", which was initiated 20 years ago. The production of rice increased significantly and this was mainly due to the increase in rice production during dry season with the use of groundwater irrigation. In recent years, groundwater in Bangladesh has been found to be contaminated by arsenic. The chronic arsenic poisoning by drinking tubewell water has become a national problem in Bangladesh. In the arsenic pollution areas, the possible presence of high concentration of arsenic in crops produced by arsenic contaminated irrigation water is a great concern.

In many parts of this region, the groundwater happens to be contaminated with arsenic and the irrigation-based farming practices has led to high deposition of arsenic in top soils and preferential bioaccumulation of the arsenic in rice compared to other cereal grains. Currently, about 85% of the total groundwater abstraction is used for agricultural irrigation purpose (BGS and DPHE, 2001). Most investigations have focused on the risk from drinking water, but there is now widening interest in whether the poison can also be passed on in rice, through irrigated fields. A report from FAO suggests that arsenic in groundwater may pose an even more insidious thereat. The report concludes that people may be exposed to arsenic not only through drinking water, but indirectly though food crops irrigated by contaminated groundwater. Where concentrations of arsenic in soil and water are high, they found a correlation with high arsenic content in crops. As levels in the local rice were not determined in the study, although contamination of the area's water is well known. As occurs naturally in soil worldwide. Most crops don't take it up. However, rice is grown in flooded fields. That changes the soil chemistry, releasing arsenic locked up in soil minerals so it can be taken up by the rice's roots. The amount of arsenic in rice varies by local conditions. Most Bangladeshis are heavily dependent on rice for their nutrition and caloric intake. They consume on average 1,645 g of cooked rice daily and hence are at greater risk from arsenic exposure. We evaluate the potential risk of arsenic contamination of rice based on the percentage of arsenic concentration of groundwater and the proportion of rice production area in Bangladesh.

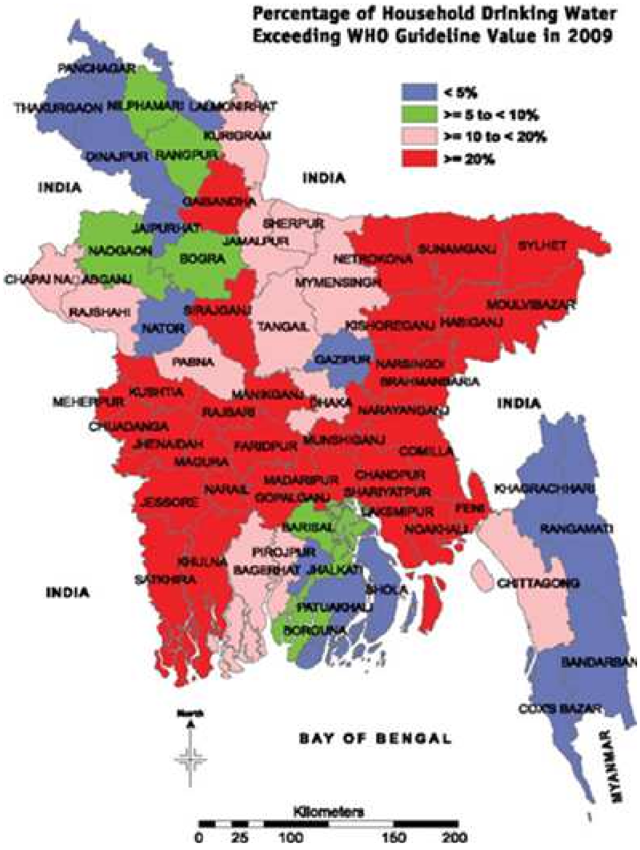


Figure 3.6 Percentage of household in Bangladesh drinking water exceeding 10 μgL^{-1} of As

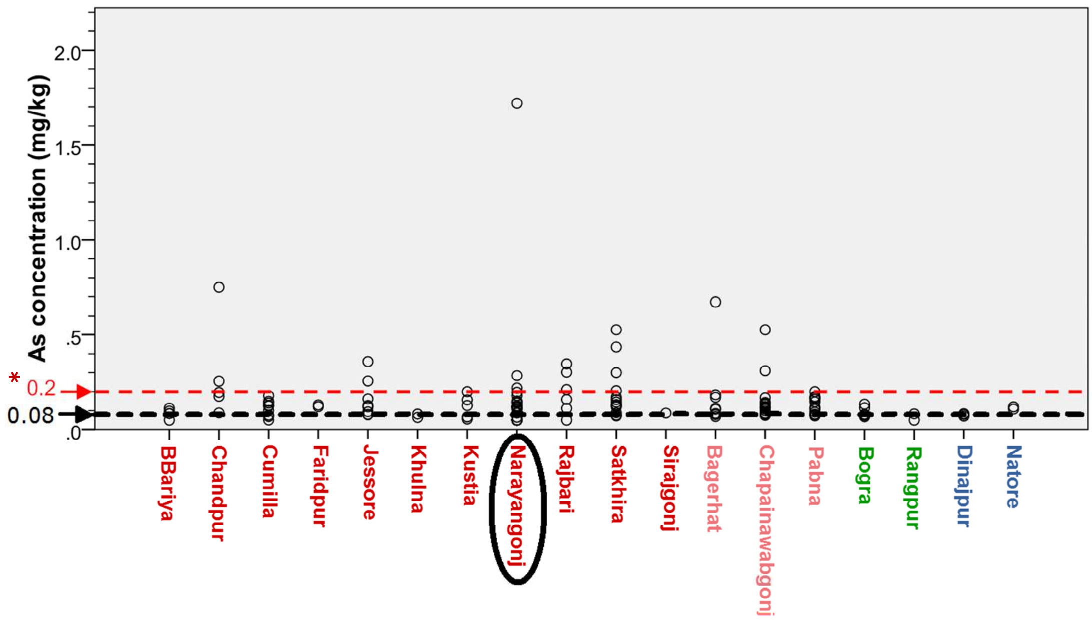


Figure 3.7 As concentrations in rice by district

The mean and range of As concentration in rice samples that were collected from Narayangonj district as well as from other parts of Bangladesh are presented in Fig. 3.7. The red lines in the figure represent the safety limit in rice (0.2 mg/kg) was calculated by Zavala and Duxbury (2008). Consumption of rice with As concentration of 0.08 mg kg-1 is equivalent to WHO guideline value of 10 µg L-1 in drinking water (Williams et al., (2006). The results shown in Fig. 3.7 plotted from high to low exposed areas and district names are written with the same color as indicated in the map shown in Fig. 3.6. Here, red color means the highly As exposed areas followed by pink, green and blue. From Fig. 3.7 it is indicated that the As concentration in rice in highly contaminated areas almost crosses this safety limit and low exposed areas is within this limit. Narayanganj is the present survey area where As concentration in rice also high. The probable reason for high concentrations of As in rice in highly contaminated areas may be due to the irrigation system. In Bangladesh, farmers use groundwater from both deep and shallow tubewells for irrigation system, and shallow tubewells, with depths of 50-70m, constitute 80-85% of the irrigation wells used for growing rice. Irrigation systems typically using in Bangladesh are shown if Fig. 3.8. According to the Department of Public Health Engineering, Bangladesh around 70% shallow tubewells (STWs) contain As > 50 ppb, and only 10% deep tubewells (DTWs) contain As around 50 ppb.

Figure 3.8 Irrigation systems of Bangladesh

3.6 Daily As intake

In the present study, the daily total arsenic intake from cooking water, rice and drinking water was estimated. Conducting the estimation, the data presented in Table 3.2 of average As concentration in rice, mean As concentration in drinking water, an individual's average rice consumption per meal and the amount of water used in cooking that amount of rice was obtained from the FFQ data. Finally, we found that the As intake of an individual from rice is 121 μg/day, as shown in Fig. 3.9. We didn't know the As concentrations in vegetables and daals. If we could know, the total amount of As intake from food would be more. From cooking water of rice and daal, the amount of daily As intake are 102 μg/person and 27.8 μg/person, respectively. In this calculation, we have considered that a person drinking an average amount of water is 2 liter/day. The As intake from drinking water is 125 μg/person/day. The results indicated that besides drinking water food is another main source of arsenic intake.

Table 3.2 Data used for estimating daily As intake

	Mean
Rice	222 g/person/meal
As in rice	0.21 mg/kg
Cooking water (rice)	629 ml/person/meal
As in water at Sonargoan thana	62.52 µg/L

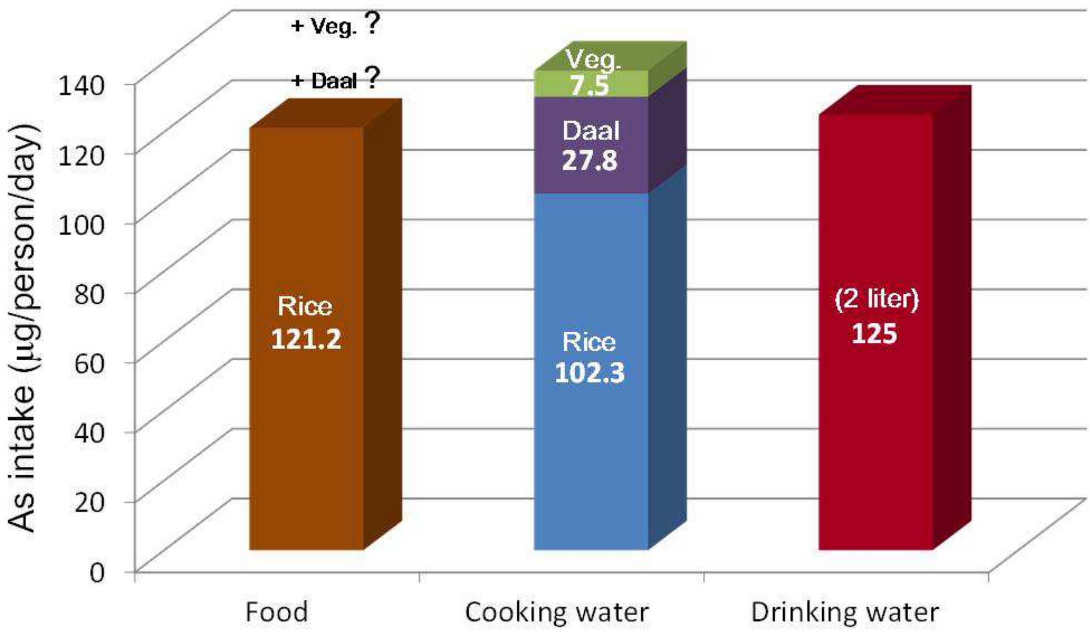


Figure 3.9 Daily As intake of an individual

3.7 Summary

In summary of this section our findings showed that there was a correlation between water and urinary As concentrations ([As]w and [As]u). To investigate the other sources the FFQ data, indicated that the most frequently consumed food was rice (more than once a day), followed by daal soup and non-leafy vegetables. Fish, meat and eggs were consumed approximately once in a week. Moreover, a large amount of water was used during preparation of rice daal soup, and non-leafy vegetables. Thus, the cooking water may have an influence on the total As intake. Food, especially rice, was another major source of As intake.

In areas where the groundwater is contaminated with arsenic, the primary routes of exposure (to arsenic) are the ingestion of the water, cooking with the water and consumption of locally grown food. Furthermore, it is important to continue to monitor the food chain because continued use of As-contaminated irrigation water is likely to increase the probability and magnitude of dietary As intake.

Chapter IV

Discussion

This study represents a consecutive study of the effect of As on intellectual function (IQ) and social competence (SC) of the children. The present research was especially focused on children who are between the age of early childhood to puberty or adolescence. Here, it is mentioned that early childhood starts from 2 to 6 years, late childhood starts from 6 to 10 years and puberty or adolescent starts from 10 to 14 years. Therefore, we have selected the children of age 4 & 5 years, 9 & 10 years and 14 & 15 years in this study, and these ages are the representatives of early childhood, late childhood and adolescent, respectively. Moreover, to assess the amount of water used in the cooking process to evaluate the relative contribution of As sources to the total As intake. Rice samples were also collected to evaluate the relative contribution of As sources. Besides these the effect socio-economic condition of the children on their arsenic contamination was investigated. In the present study, each house of the children was visited. Household demographics (e.g, parental education, occupation, income, housing type, sanitation, etc.) and questions about drinking water were asked to the parents and children. In the present study area most of the inhabitants mainly drink and use groundwater through tubewells in their daily life. The groundwater is polluted with severe As poisoning. The water arsenic concentrations of some tube wells in the children’s house from different villages have been tested instantly as a part of initial assessment. Villages of Sonargong thana at Narayanganj districts are isolated low-income areas with less economic development and have a relative lack of communication with the outside world; resulting in poor living conditions for the majority of the residents.

However, the subjects were divided into 3 groups by applying referential levels of $[As]_u$. There are more referential values especially in “non-effective levels”, however, they did not change the findings observed in this study.

4.1 Socioeconomic status as confounding factor of arsenic exposure

Socioeconomic status (SES) especially income was related with $[As]_u$. This is partly because inhabitants with low income cannot afford to change their tubewells even if they know that it contains high As. Mostly rural people could not take any step to take As free water due to their poor SES. Among the children, who knew about the arsenic in their drinking water, 74% of the respondents had got information from the different NGO health workers. The respondents have also asked about the cause of using the highly arsenic contaminated drinking water and most of them said that they could not afford safe water and because of the distant of safe water source. Some respondents said, they don’t think their drinking water is risky for their health. Among the respondents, 73% of the students who have no alternate drinking water source, 19% are drinking water from the other tubewell, and only 7% respondents who could afford to dug own second tubwell for safe water. Thus the poor socio-economic condition may propagate the As contamination.

The households are mainly engaged in farming and wage labor. Though a considerable number of households were in the businessman category, they are actually engaging in a very small business like vegetable selling, shop keeping, etc. Bangladesh is a developing country with the majority of households falling into the low income stratum. Thus, the participating households in this study belonged to low to low-medium strata. More than 20% of the respondents are illiterate, and 37% just attended in the primary education. These findings are in agreement with the findings of other researchers (Dey and Ali, 2011; Hadi, 2003; Amin *et al.*, 2011). Dey and Ali (2011) found that ultra poor (17%) and poor (20%) households drink much more arsenic contaminated water than the non-poor (16%) households. Hadi (2003) concluded that socio-economic status variables were related to the arsenic exposure and knowledge of the health problems. However, Amin *et al.*, (2011) depicted that water consumption was found to be correlated with socio-economic factors such as household size, house quality, income etc. Financial inabilities for installing deep tube well, non-availability of arsenic-free tube well water, unmarked tube well whether contaminated by arsenic and not, were identified as the major reasons for drinking arsenic contaminated tube well water by the households. Though some researcher stated that As poisoning also deteriorates the SES: losing jobs, barriers to access new jobs, social rejections, spending a big proportion of money for treatment.

4.2 Arsenic effect on IQ of children

Urinary arsenic had an association with IQ for 14 & 15 year and 9 & 10 year age groups; while association only found with nonverbal IQ for 4 & 5 year age group children. Because As is neurotoxic (V.M Rodriguez et al. 2003). And As can affect brain function of children through maternal exposure. Chattopadhyay *et al.*, (2002) stated that oxidative stress reactions may be involved as arsenite inhibits glutathione reductase in brain tissue. However, in vivo inhibition of glutathione reductase was only found at very high concentrations of As. Although in the latter study, arsenic metabolites MMA and DMA were measured in brain tissue of mice, the mechanism by which arsenic crosses the blood brain barrier and the role of arsenic methylation in neurotoxicologic effects are not known. From the result we found that children from early childhood age, verbal and composite IQ were unaffected. The possible explanation for the differences observed across the age groups implies that there might have lower stability of estimates of children's intelligence at younger age (e.g., Bartels *et al.* 2002; Petrill *et al.* 2004). The results of the present study are consistent with the findings recorded by Wasserman *et al.*, (2004, 2007) of an inverse correlation between intelligence and water arsenic. They conducted their study on As exposure in 10-year-old children and found a stronger association of IQ with As in tubewell water than with urinary As. Wasserman *et al.* (2007) also study on As exposure in 6-year-old children and reported that with covariate adjustment, water As remained significantly negatively associated with both performance and processing speed raw scores; associations were less strong than in their previously studied 10-year-olds. However, in the present study, a stronger association was found for IQ with urinary As than with the As in tubewell water, and the existence of stronger association is more reasonable because urinary As concentration reflects the total ingestion of As from all possible sources. Wasserman *et al.* (2004, 2007) did not find an association between As exposure and aspects of verbal intelligence in their studies on both age groups. In the present study, it was not found any association between As exposure and aspects of verbal intelligence of children who were from 4 & 5 year age group. However, significant relationship between As and verbal intelligence of children reported in some studies that were conducted in other part of the world. For example, controlling demographic covariates, a negative association between urinary As and verbal intelligence was reported among 80 children living near a lead smelter in Mexico (Calderon *et al.* 2001). Another small pilot study of 31 children, 11–13 years of age, residing in a former lead and zinc mining site containing tons of mining waste, or chat (Wright *et al.* 2006), found adverse associations between both hair As and hair Mn, and general intelligence scores, particularly verbal scores. The possible cause of not finding any association between As exposure and aspects of verbal intelligence for early childhood age groups, in this study, might be the lack in development of higher cognitive function especially language and hearing. In one of the study, C.A Nelson, 2000 reported that the human brain development especially the higher cognitive function starts from birth to around 15 years old of children, and the language and sensory pathways (vision, hearing) are developed until 6 years old. Apparently, the younger children (4 & 5 years old) in the present survey felt shame to answer because it was an individual test. On the contrary, group tests were applied to measure the IQ of children who are from the age of late childhood and adolescence; they felt free to answer. However, we could not use the same SPM test among all the children from different representative groups because there is an age limitation of using SPM.

4.3 Arsenic effect on SC of children

Urinary arsenic $[As]_u$ had an association with SC. Since it was mentioned earlier that As is neurotoxic and affects the brain function. Psychosocial state (worry, loneliness, negative evaluation by others) and brain function (IQ) may influence how one acts and thinks and this could in turn affect one's SC. Moreover, As may influence the executive functioning of brain and which can influence an individual's ability to interact socially. SC is a multifaceted developmental process that begins in childhood (Hussong *et al.*, 2005). Cognitive development plays a huge role in socialization. The way in which a child achieves social competence not only depends on how others identify him/her, but how that particular child identifies with his/herself. Cognitive developmental theory states that in order for social interactions to take place, a self-concept must first develop (Shaffer, 2005). One of the main developmental tasks during childhood is to achieve competence within social relationships. Many theories suggest that early influences in life are highly correlated with how well a child will later develop socially. All the respondents were asked about their social and psychological consequences, and they replied that they are worried about arsenic and about their future life. Around 45% children, they said that their relatives such as parents, grandparents, siblings had physical symptoms. Therefore, they are negatively evaluated by others. We know that children's external environments, such as neighborhoods, play an important role in the development of social competence in children. Sheridan *et al.* (2003) noted important parental choices such as choosing positive neighborhoods and schools as an influence on the development of social competence in children. Around 2% children showed their physical symptoms like melanosis or keratosis, and they feel shame and loneliness. Childhood loneliness, however, can be mediated, in part, by learning social skills (Ditommaso *et al.*, 2003). If a child feels rejected when they are around their peers, it would seem likely that a child would develop low self-esteem about themselves. Feelings of lower self-worth and psychopathology in adulthood have been linked with lower peer acceptance and greater peer rejection in preadolescence (Bagwell *et al.*, 1998). Maladjustment in social aspects of a child's life may hinder an adaptive transition into adulthood, which may cause social isolation as an adult (Ditommaso *et al.*, 2003). Children with friends have greater academic success when compared with their peers who do not have friends (Parker & Asher, 1993). Therefore, gaining social competence as a child may increase the likelihood of greater academic achievement in school. Some of the children especially girl they feel shy to show their physical symptoms. As we stated before the main factors that significantly contribute to and influence the development of social competence, one of them is personality/innate characteristics of the child. All humans have different personality characteristics, partially because of their different genetic makeup. However, humans are born with only certain capabilities because of their genetic makeup. The frontal lobe is a section of the human brain that controls many processes and functions (Anderson *et al.*, 2001). One of the functions that are controlled by the frontal lobe is executive function. The concept of executive functioning can be described as a set of cognitive abilities, such as learning social skills, which control and regulate behaviors and other abilities (Anderson *et al.*, 2001). When an individual displays social competence, they possess the ability to apply social skills according to the rules of social interaction and have the ability to adapt to a situation using skills such as impulse control and behavioral adaptation. The inability to be flexible and apply behavior according to social rules is considered to be social incompetence. Executive functioning is needed for goal directed behaviors such as planning and utilizing working memory, as well as inhibitory impulse control, attention shifting, and initiating and stopping actions (Anderson *et al.*, 2001). In other words, many of the cognitive abilities that are a part of executive functioning appear to be fairly congruent to the skills necessary to be socially competent, such as behavior regulation and problem solving. Therefore, the skills necessary to become socially competent are partially due to innate characteristics such as executive functioning (Riggs, Johromi, Razza, Dillworth-Bart, & Mueller, 2006).

During the interview, we have also come to know that some of the student’s family members had died due to this arsenic poisoning in the groundwater. Sometimes it is difficult to attend school for them because of their friend and teacher’s avoiding. These avoiding created due to their lack of knowledge about arsenic. One of the domains that influence a child's development of social competence is the school environment. Sheridan *et al.* (2003) pointed out the significant role that teachers play in helping to develop a child's social competence. For nearly all children, the most social place is in the classroom at school. Schools are critical places to promote the importance of not only cognitive aspects (i.e. learning), but also behavioral and emotional aspects (Warwick *et al.*, 2005). The school has a large influence on the development of social competence throughout childhood. The school is a place where children develop many competencies through relationships that define the child's self and abilities. Children would need positive reinforcement from their peers to increase the social competence. That's why these factors can be influence the SC scores. The previous study stated psychosocial problem of adult. As contamination in groundwater is problematic not only as a health hazard but also as social problem in Bangladesh. There has been little or no social education concerning the treatment of persons affected by As poisoning. Because of illiteracy and lack of information, many confuse the skin lesions with leprosy, which among village people is considered a contagious killer. As a result, those who have early symptoms of arsenicosis do not disclose their condition to avoid certain ostracism. When family members come to know of a sufferer's warts and black spots, they tend to avoid direct contact with the affected person. Sufferers in rural areas are not allowed to appear in public. Affected school-age children are prevented from attending schools and are avoided by their friends and classmates. Adults are barred from attending cultural/religious functions. Often, when employers discover their affliction, the affected workers immediately lose their jobs. Once detected and dismissed from an employment because of arsenicosis, no other local employer will provide them with alternative employment. Under such circumstances, many have no option but to migrate to urban areas. Here it is mentioned that there is no systematic study especially about children' social competence and arsenic exposure, and this is the first systematic study about children SC.

Besides, the result also shown that the children who came from the family of having higher SES they posses higher scores in IQ percentile and as well as in social competence. In addition, hypothetically it seems that the children who are intellectually good, they are socially highly competent. So the children who are intellectually good they can solve the problem well and cooperative actively and self esteem is high. By the way their social competence is high. Therefore, SC is important because it is associated with many positive outcomes such as prosocial behavior and overall happiness as an adult/ person/an individual.

4.4 Arsenic in urine $[As]_u$ and tubewell water $[As]_w$

Drinking water $[As]_w$ and urinary $[As]_u$ were positively correlated with each other. Because $[As]_u$ reflects the recent exposure from all possible sources, this correlation indicates that the respondents were exposed to As not solely through drinking water. Prior to data collection, some tubewell water from different villages was randomly inspecting using an arsenic test NIPSOM kit to assess the arsenic contamination level. Surprisingly, the As concentration $[As]_w$ in some of the respondents' tubewell water was determined to be in the safe range; however, their urine test results revealed the presence of a high concentration of arsenic $[As]_u$. This indicates that they are ingesting As from other sources, such as food or water used for cooking. Here it is mentioned that the present consecutive study was started in 2010 until 2012 in the same population of different age groups. Initially the villagers knew a little about As, but we also observed in 2013 that many families shifted their water consumption from well with high in As to one with less As because of improving their consciousness. Some of the children's parents were stopped drinking water from contaminated tubewells but continued to use that contaminated tubewell water for cooking purpose. They believed that the heat in the cooking process evaporates and destroys the As from water, as occurs with some microbes.

4.5 Cooking water and food as potential sources of arsenic intake

From the results it was found that the major source of water consumption was cooked rice, followed by daal soup. Rice is the staple food in Bangladesh and a large amount of water was used in cooking. Daily As intake from raw rice was almost equivalent to that from 2 liters drinking water per day. In addition, although it is apparent that drinking water is the major source of As for the population living in As-affected areas in Bangladesh, our results suggest that the cooking water and food especially rice are another sources of As intake. Many reports have relied on the concentrations of As in drinking water (Mazumder *et al.*, 2008) as the surrogate of human exposure; however, however, the additional exposure through raw and cooked food should not be neglected. The biological dose indicators would neither give any information on the absolute intake level nor on the relative relevance of different arsenic sources, especially the importance of water versus food arsenic, which would be important in establishing risk assessment and in determining the priority for mitigation. In the present study, the relative contribution of As sources to total As intake was evaluated systematically by assessing the As concentrations in drinking water and rice, and the proportion of water added in cooking.

From the results, As concentration in rice was high in highly contaminated areas of Bangladesh. Cultivations of rice are largely dependent on groundwater irrigation (Dey *et al.*, 1996). In last few decades thousands of high capacity, large diameters motorized pumps have been installed to meet this irrigation requirement (Norra *et al.*, 2005; Neidhardt *et al.*, 2012). Currently, about 85% of the total groundwater abstraction is used for agricultural irrigation purpose (BGS and DPHE, 2001). The groundwater irrigation is highest during the dry season rice (*Oryza sativa* L. Boro) cultivation, which solely relies on groundwater irrigation (Dey *et al.*, 1996). Meharg and Rahman (2003) have reported that for Boro rice cultivation, about 1000 mm irrigation water is required per hectare. These pumps are mostly abstracting groundwater from shallow aquifers, which are heavily contaminated with dissolved As. Consequently, As is increasing on the top soil of the irrigated lands. Meharg and Rahman (2003) have estimated that if irrigation water contains 100 μg L^{-1} of As, the annual accumulation of As in the paddy soil would be as high as 100 mg m^{-2}. By monitoring As concentration in the Bangladeshi paddy field soil over a period of 3 years, Dittmar *et al.* (2010a) have further predicted that continuation of current irrigation practice would increase the As concentration in top 40 cm of the paddy field soil by a factor of 1.5 to 2 by the year 2050. The increased As concentration in the irrigated lands ultimately results in the accumulation of As in the food crops cultivated on these lands (Meharg and Rahman, 2003; Roberts *et al.*, 2007; Dittmar *et al.*, 2010b; Roberts *et al.*, 2010; Spanu *et al.*, 2012). In Bangladesh, the concentration of As in rice grains positively correlates with As concentration in irrigation water (Zavala and Duxbury, 2008). General cultivation practices such as continuous flooding of the irrigation land for the cultivation of rice also facilitates As mobilization in the rice fields. Continuous flooding of the lands leads to soils becoming reduced with time during rice cultivation, which increases the bioavailability of As in the soil pore water by reductive dissolution of As hosting mineral phases such Fe oxyhydroxides in the soils (Marin *et al.*, 1993; Abedin *et al.*, 2002; Meharg and Rahman, 2003; Roberts *et al.*, 2011; Spanu *et al.*, 2012). As a result, the accumulation of As in rice is comparatively 10 fold higher than other cereals (Williams *et al.*, 2007; Raab *et al.*, 2009). Several studies have already reported the accumulation of As in rice grains cultivated in this regions (Roychowdhury *et al.*, 2002; Duxbury *et al.*, 2003; Meharg and Rahman, 2003; Roychowdhury *et al.*, 2003; Meharg, 2004; Williams *et al.*, 2005, 2006, 2007; Mondal and Polya, 2008; Roychowdhury, 2008; Zavala and Duxbury, 2008; Panaullah *et al.*, 2009; Bhattacharya *et al.*, 2010).

Chapter V

Conclusions and Recommendations

This study reports that the people in the present survey area are using water form highly As contaminated tubewells. Socioeconomic status (SES), especially household income, was determined to have a dominant role on As contamination. Water and urinary As concentrations ($[As]_w$ and $[As]_u$) were correlated with each other. Arsenic had an effect on IQ of children in all age groups and on SC of children in late childhood and adolescence. High concentration of $[As]_w$ or $[As]_u$ was associated with lowering the IQ percentile and score of SC. The present survey suggests that the water used for cooking is an important source of As and thus, the cooking water may have an influence on the total As intake. Rice is another major As source among Bangladeshi foods.

Our findings can play an important role in facilitating the appropriate steps in the mitigation of As poisoning from all possible sources, such as drinking and cooking water, which will thus reduce the total As intake and, accordingly, improve rural livelihood in Bangladesh. The most important action in affected communities is the prevention of further exposure to As by the provision of safe water supplies for drinking, food preparation and irrigation of food crops. Moreover, we hope that our findings will add a new sense of urgency to mitigate As exposure in Bangladesh and other parts of the world where consumption of As-contaminated groundwater is prevalent.

Finally, it is necessary to conduct more research in the early age group children (age < 4 & 5 year) in order to fully define the stage at which children are most vulnerable to As exposure. Moreover, future research should focus on all possible sources of As intake.

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